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PRELIMINARY HYDRODYNAMIC MODEL TESTS OF SEVERAL LVA PLANING HULL CONCEPTS

by

Daniel Savitsky

Edward Numata

Michael Chiocco

Prepared for
Code 03221 of Naval Sea Systems Command
under
Office of Naval Research Contract
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ABSTRACT

Exploratory hydrodynamic model tests were conducted to investigate the resistance and seakeeping character of two possible LVA planing hull forms. Additional studies were made to evaluate the effects on hydrodynamic performance of adjustable transom flaps and fixed chine flaps. For a 55,000 lb. gross weight, the planing inception speed was between 10 and 15 knots. The impact accelerations and motions in a head sea state 2 are comparable with those observed for well-designed planing hulls and appear to be within the requirements for maintaining proficiency as defined by MIL-STD 1472-A. The added resistance in a head sea is larger than for conventional planing hulls. Bow form improvements are recommended to reduce the resistance and accelerations in a seaway. Computed and measured values of EHP and trim for zero flap deflection are in good agreement.

KEYWORDS

Planing

Seakeeping

Amphibious Craft

INTRODUCTION

One of the possible versions of the LVA is a low deadrise, hard chine, planing hull. Because of the dimensional constraints and large loadings associated with its mission, the bottom loading of the LVA is considerably larger than conventional planing craft. As a consequence, the running trim and drag-lift ratio at hump speed have been estimated to be larger than that of conventional planing hulls. In order to provide some hydrodynamic design guidance for an LVA planing concept, an exploratory model test program was undertaken to define the smooth water resistance, and motions, impact loads and resistance in a head sea state 2 for a range of speeds and loadings.

Two basic planing hull configurations were model-tested. One was a so-called inverted vee-bottom which was developed by the LVA office at NSRDC and the other was a flat-bottom planing hull. The overall dimensions and loadings were the same for both models. Adjustable aluminum transom flaps and fixed chine flaps were added to the basic hull models in order to evaluate their hydrodynamic effectiveness in smooth and rough water.

The model test results were analyzed to identify the EHP requirements; estimate personnel tolerance of g loads in a seaway; effectiveness of transom and chine flaps; adequacy of predictive techniques; and hull form changes to improve hydrodynamic performance. Basically, the tests were expected to provide fundamental hydrodynamic data related to highly-loaded planing hulls in smooth and rough water and to identify possible options in the LVA design process.

This study is in support of a development program initiated by Code 03221 of the Naval Sea Systems Command. The work was carried out under Office of Naval Research Contract N00014-75-c-0746, Project NR 062-510. Technical monitoring was provided by the LVA office at NSRDC.

MODELS AND APPARATUS

The test models were 1/12-scale and were constructed of fiberglass-covered polyurethane. The inverted vee-bottom hull was constructed in accordance with prototype drawings supplied by NSRDC (Figure 1) and is referred to as the P-1 model. It is seen that the inverted vee cross-section exists primarily in the bow area and reduces to zero deadrise at the stern. The flat bottom hull model was developed by the Davidson Laboratory and is shown in Figure 2.

An adjustable, partial span, transom flap having a full-scale chord of 3 ft. and a span of 6.5 ft. was hinged to each hull bottom at the aft "break" point in the buttock lines (Figure 3). This flap was capable of deflecting downward to a maximum of 15° in 2.5 degree increments. A zero degree flap angle refers to the flap oriented as a horizontal extension of the planing bottom. The flap is hinged at the aft break point in the buttock lines since this is the point of flow separation when planing without transom flaps. Although negative flap angle settings were available, this variation was not model-tested in the first exploratory study. Further, the flap chord was fixed at 3 ft. although large flap sizes could be easily accommodated. One brief series of smooth water tests were made with a full span flap installed on the flat bottom hull. (Figure 3)

Both model forms were tested with and without 3 ft. (prototype size) wide chine flaps attached to each side of the model. These chine flaps started at the break point of the aft buttock lines and extended forward nearly 2/3 of the hull length. (Figure 3)

Each hull bottom was inscribed with black lines, one tenth of a foot apart, to estimate wetted lengths from underwater photographs. Side wetted lengths were obtained from similar side markings. The model tow pivots and heave reference were located at the model CG for all configurations. The weights of the heave mast, pivot box, drag balance, and three accelerometers were included in the ballasting for each condition. The stern and bow accelerometer positions were on the centerline four (4) and twenty-four (24) feet from the transom, respectively, for all cases. The bow accelerometer is located in the anticipated pilot station and the stern accelerometer is in the troop compartment of an LVA.

Full-scale characteristics of the tested configurations were obtained from the LVA office of NSRDC and are as follows:

	LVA P-1			LVA Flat Bottom Hull**
	50,000#	*55,000#*	*60,000#*	*55,000#*
LOA, ft.	28	28	28	28
Beam, ft.	11	11	11	11
Hull Depth, ft.	7	7	7	7
LCG Fwd Transom ft.	12.5	12.5	12.5	12.5
	-	13.5	-	-
VCG Above Baseline, ft.	3.5	3.5	3.5	3.5
Mean Draft, ft.	3.07	3.35	3.58	3.35
Pitch Gyradius, ft.	7	7	7	7
Static Floating Trim, deg.*				
LCG 12.5	-0.1	0	0.1	0.6
LCG 13.5	-	-3.2	-	-

**Plus trim means bow up*

***A 0.5 ft. by 11 ft. spray deflector normal to the bow at a point 4' above the baseline was fitted to the craft prior to irregular seas testing.*

TEST PROCEDURE

The models were towed over a simulated full-scale speed range of 10 to 40 knots in calm water to obtain trim, heave, wetted length and resistance data for use in determination of smooth water EHP and as a basis for evaluating added EHP when running in a seaway. Model resistance was expanded to full size in salt water at 59°F based on the ATTC model-ship correlation coefficients with zero roughness allowance. Proper allowance was made to simulate thrust unloading when the model was trimmed. The propeller axis was taken to be parallel to and 1.25 ft. below the base line.

The model was towed at constant speeds over the speed range into irregular head sea state 2 with significant full-scale wave height of 2.2 ft. In Reference 1, it is shown that rough water testing of planing hulls provides similar results at either constant speed or constant thrust. Resistance, pitch and heave about the CG were measured with linear differential transformers, and accelerations normal to the baseline at stern, CG, and bow were measured with linear accelerometers with a frequency response flat to 100 hertz. A standard Davidson Laboratory resistance-type wave wire was used to measure waves at a fixed point in the tank. Data were transmitted to shore through overhead cables and were recorded in analog form on magnetic tape and simultaneously as time histories on a direct writing oscillograph. Data were recorded for a distance of 50 feet in calm water and 140 feet in irregular seas.

During the tests, the transducer outputs were processed on-line by a digital computer to furnish statistical averages of the craft responses. This output included mean drag, average running trim and heave; also averages of 1/3-highest of upward acceleration at the stern, CG, and bow and of pitch and heave amplitudes. Average trim is the inclination of the craft's baseline to the horizontal; average heave is referred to a static floating zero; acceleration is a change from a floating zero. Because of the exploratory nature of this initial test program, approximately 25 - 30 waves were encountered during a test run. An ideal statistical sample usually contains approximately 100 wave encounters. Nevertheless, it is believed that the present test results are adequate for the purposes of this exploratory study.

The reproducible irregular seas generated in the Tank 3 facility of the Davidson Laboratory approximate the Pierson-Moskowitz spectrum shape. The spectrum used in this investigation is presented in Figure 19 and compares with the Pierson-Moskowitz spectrum. Color 16mm silent motion pictures were taken for part of each run tested. When viewed at a projection speed of 16 frames per second, a full-scale time for each prototype is simulated. A movie sequence is presented in Appendix A. Video tape records were obtained for all runs. A test matrix for each configuration is presented in Appendices B, C and D.

A matrix of smooth water test conditions is given in Appendices B and C. The rough water test matrix is given in Appendix D.

TEST RESULTS

All model test results have been extrapolated to full-scale values and are so presented in this report.

Smooth Water Results

Results for all configurations and test conditions are presented in Tables 1 through 7 and in chart form in Figures 4 through 11. It will be noted that the tabulated values include test speed, transom flap deflection, drag, EHP, equilibrium trim of the base line, CG, heave relative to the static floating position, maximum wetted length, and total wetted areas including bottom and side wetting. EHP is defined as bare hull resistance multiplied by speed and divided by 550. An estimate of the shaft horsepower (SHP) is dependent upon the appendages, propeller characteristics and machinery which have not been considered in this study. Tables 1, 2 and 3 and Figures 4, 5 and 6 represent results for the inverted vee-bottom (model P-1) without chine flaps for gross weights of 50,000 lbs., 55,000 lbs. and 60,000 lbs. respectively--all for an LCG of 12.5 ft. forward of the transom. Table 4 and Figure 7 present similar results for the P-1 for a gross weight of 55,000 lbs. and the LCG moved to a distance of 13.5 ft. forward of the transom. Table 5 and Figure 8 present the data for the P-1 with added fixed chine flaps at a gross weight of 55,000 lbs. and an LCG of 12.5 ft. forward of the transom. Data for the flat bottom hull with and without chine flaps for a loading of 55,000 lbs. and an LCG of 12.5 ft. forward of the transom are given in Tables 6 and 7 and Figures 9 and 10. A summary plot of smooth water EHP is given in Figure 11.

Rough Water Results

Table 8 presents rough water test results for the P-1 model with and without chine flaps and for the flat bottom model with chine flaps. These were the only configurations tested in a seaway. The data are retabulated in Table 9 for ease in comparing the behavior of the three hull forms. In addition, Table 9 also contains listings of the smooth water trim angles for identical test conditions. All data are also plotted in Figures 12 through 18.

In order to put the LVA impact data into proper perspective, the significant center-of-gravity accelerations are compared in Figure 20 with some ad hoc planing hulls previously tested at Davidson Laboratory. These data are also presented as 1/3 octave band rms g's versus encounter frequency and compared with MIL-STD 1472A habitability criteria in Figure 21.

Color 16mm silent motion pictures of selected test runs have been submitted to NSRDC.

DISCUSSION OF TEST RESULTS

Smooth Water Performance

Referring to Figure 5, which is a summary of test results for the P-1 hull operating at a gross weight of 55,000 lbs. and an LCG 12.5 ft. forward of the transom, the following hydrodynamic characteristics are evident.

0^o Transom Flap and No Chine Flap: With zero transom flap, the hump speed is approximately 15 knots, the trim angle is nearly 22^o, and the EHP is 1050 hp. Both the trim and horsepower decrease rapidly as the speed is reduced. For instance, at 10 knots, the trim angle is nearly zero and the EHP is only 100 hp. As the speed is increased beyond 15 knots, there is a rapid decrease in trim angle and only a slight decrease in EHP. At 15 knots, the craft was fully planing in the sense that the flow separated clearly from the chines and transom.

Effect of Transom Flaps: The effectiveness of the transom flap is clearly demonstrated in Figure 5. It is seen that, for full flap deflection of 15^o, and at a speed of 15 knots, the hump trim angle is reduced to 15^o and the EHP is decreased to approximately 800 hp--nearly 300 hp less than for the 0^o transom flap position. A larger flap or a flap deflection greater than 15^o is expected to further reduce the hump trim and resistance. At speeds in excess of 15 knots, smaller flap angles are required to achieve minimum drag at a given speed. For instance, at 25 knots a 12.5^o flap angle is required; at 35 knots a 10^o flap angle is required, while at 40 knots a 7.50 flap angle is used. At these higher speeds, greater flap angles would develop diving moments that would immerse the bow and, hence, increase the drag. This effect is demonstrated at 35 knots where it is seen that an increase in flap deflection from 10^o to 12.5^o increased the EHP by nearly 300 hp. In fact, the transom flap enables the craft to approach an optimum trim angle of approximately 4^o where the lift-drag ratio is a maximum. This first exploratory study was not intended to develop the best flap configuration but rather to demonstrate their effectiveness. It is believed that, based upon these data and available analytical procedures (Ref. 2), an optimum flap can be designed for a heavily loaded planing hull.

Effect of Chine Flaps: Figure 8 presents results for the P-1 model with added chine flaps for a gross weight of 55,000 lbs. and an LCG of 12.5 ft. forward of the transom. A comparison of these results with those in Figure 5 at optimum transom flap deflection leads to a direct evaluation of chine flap effectiveness. It is seen that, for maximum deflection of transom flap, the addition of the chine flaps results in a hump EHP of 680 hp compared with 810 hp for the case of no chine flaps. At 35 knots, the addition of chine flaps reduced the EHP from 760 hp to 600 hp. In addition, the running trim angles for the entire speed range were less than those for the P-1 without chine flaps. This is a direct consequence of the lower beam loading associated with the addition of the chine flaps.

As with the case of the transom flap study, no attempt was made to optimize the chine flap design. However, the use of the present data and the analytical procedures of Ref. 3 can achieve this optimization. It does appear that the addition of chine flap is hydrodynamically beneficial in the planing range and may present an option in the total craft design. One other possible advantage offered by the chine flaps is that, at pre-planing speeds, the submerged chine flaps should increase the damping in roll, heave, and pitch and thus mitigate the motions while loitering in a seaway.

Effect of Increased Displacement: A comparison of the results in Figures 5 and 6 shows that, at 35 knots, an increase in displacement from 55,000 lbs. to 60,000 lbs. (9.1%) results in approximately a 9% increase in maximum EHP. This is in direct proportion to the increase in gross weight and follows from the fact that the transom flap angle was adjusted so that, for both gross weights, the model ran at essentially the same trim angle. It is, of course, well known (Ref. 3) that the lift-drag ratio of a planing hull is primarily dependent upon the running trim angle. At hump speed, the EHP for the 60,000 lb. gross weight is nearly 18% larger than for the 55,000 lb. case. The running trim for the heavier gross weight was larger than for the light weight due to the fact that the transom flap was set at maximum deflection (15°) for both loadings. It is believed that, with more transom flap available at the hump condition, the hump trims for both displacements could be made identical and, hence, the EHP would increase in direct proportion to the increase in gross weight.

Effect of LCG Position: The effect of forward movement in LCG was investigated with the P-1 model at a gross weight of 55,000 lbs. Table 2 presents data for an LCG of 12.5 ft. forward of the transom while Table 4 presents data for an LCG of 13.5 ft. At 15 knots and a transom flap deflection of 15°, the forward LCG resulted in a reduction of running trim from 15.2° to 10.9°. Ordinarily this should reduce the EHP. However, it is seen that the EHP actually increased. This follows from the fact that, at the forward LCG, the bow immersion increased, thus increasing the drag. It is believed that a transom flap angle deflection less than 15° would have reduced the bow immersion and, thus, avoided the large drag increase. At 35 knots and a transom fl p deflection of 7.5°, the forward LCG reduced the trim angle from 4.1° to 3.7° and increased the EHP from 750 to 837 hp. This increase in EHP follows from the fact that 3.7° trim is less than the optimum trim (between 4° and 5°) where the lift-drag ratio is a maximum. It appears then that a forward LCG can be accommodated by the use of transom flap angles smaller than those used for the aft LCG position and thus reduce bow immersion. Aft center-of-gravity positions were not investigated in this study. However, it can be postulated that the higher trim angles which will be associated with an aft LCG can be overcome by the use of transom flap size and settings greater than those for the mid LCG position, particularly at hump speed.

Maximum Lift-Drag Ratio for P-1 Model: It is interesting to note from the data given in Table 5 that, at 35 knots, the P-1 model with chine flaps and optimum transom flap setting has a lift-drag ratio of 55,000/5590 = 9.8. This is a somewhat higher value than experienced for typical planing hulls. It is attributed mainly to the effect of the transom flap increasing the pressures on the aft end of the basic planing bottom and, hence, improving its hydrodynamic efficiency.

Effect of Zero Deadrise: A comparison of the EHP for the inverted vee bottom hull without chine flaps (Figure 5) with the EHP for the flat bottom hull without chine flaps (Figure 9) shows that, at optimum transom flap angles, the flat bottom hull requires nearly 40 hp less than the P-1 for most of the speed range. This follows from the slightly smaller trim angle associated with the flat bottom hull. Comparing the P-1 and zero deadrise hulls with chine flaps (Figures 8 and 10) at a gross weight of 55,000 lbs. and an LCG of 12.5 ft. forward of transom shows an essentially similar result.

Effect of Large Transom Flap: For all configurations and loading previously discussed, the EHP at hump was always somewhat larger than the EHP at 35 knots. This was attributed to the large trim angle at hump which could not be further reduced with the limited size of trim flap used in the study. A brief investigation was made of the effect of a full-span transom flap attached to the flat bottom hull with chine flaps. It is seen (in Figure 10) that, for a 2.5° deflection of the large transom flap, the EHP at hump was reduced to approximately 560 hp--just about equal to the EHP at 35 knots. Further exploratory studies to reduce the hump trim are recommended. The present test results and the analytical methods of Ref. 2 and 3 provide the guidance for flap design.

It is interesting to note from the data given in Table 7 that, at 35 knots and a transom flap setting of 5.0°, the flat bottom hull with chine flaps has a lift-drag ratio of 10.3. This is somewhat larger than obtained with the P-1 at 35 knots.

Porpoising Tendency: For the P-1 and flat bottom hull, porpoising was observed at 30 knots with the LCG at 12.5 ft. forward of the transom and with the transom flap set at zero degrees. A 2.5° increase in transom flap angle completely eliminated all porpoising tendencies.

Summary of Smooth Water EHP: Figure 11 presents a summary of EHP versus speed for the four tested configurations at a gross weight of 55,000 lbs. and an LCG of 12.5 ft. forward of the transom. This plot demonstrates the reduction in smooth water EHP which is associated with controllable transom flaps and chine flaps. In the extreme case, it is seen that, at hump speed, the EHP of the P-1 with 0° transom flap and no chine flap is 1,075 hp which, for the flat bottom hull with chine flaps and a large transom flap, the EHP is reduced to 550 hp. Similar reductions in EHP are seen at 35 knots. Although flaps do appear to offer hydrodynamic advantages, their incorporation in an LVA prototype is recognized to be dependent upon considerations of additional design aspects.

Performance in Head Sea State 2

It will be recalled that rough water studies were made only with the P-1 hull; the P-1 hull with chine flaps and the flat bottom hull with chine flaps. The loading was always 55,000 lbs. with the LCG 12.5 ft. forward of the transom. In all cases, the transom flap was included. The following discussions will be based on the data plotted in Figures 12 through 18. Statistical results are presented since motions and accelerations of planing craft are non-linearly dependent upon wave height (Ref. 1).

Significant Pitch Motions: Figure 12 demonstrates the variation of significant pitch oscillations (bow up or down) with speed about the mean pitch given in Table 8. It will be recalled the significant pitch values represent the average of the 1/3 highest values obtained in a test run. In all cases, it is seen that transom flap deflection is most effective in reducing the pitch oscillations. For example, at 25 knots, the pitch amplitude is 6^{o} for the P-1 without chine flaps and 0^{o} transom flap. The pitch amplitude is reduced to 2.7^{o} for a transom flap deflection of 12.5^{o}. An examination of Figure 12 shows that it is possible to limit the pitch amplitude to approximately 2.5^{o} for all speeds and all tested configurations. This pitch value is comparable to those experienced by conventional planing hulls.

Significant Heave Motions: Figure 13 demonstrates the variation of significant heave oscillations (up or down) with speed. Again, it is seen that, with proper transom flap selection, the heave oscillations can be limited to values between 0.5 ft. and 1 ft. for the entire range of test speeds and for all configurations. The trend is for heave oscillations to decrease with increasing transom flap deflection. This follows from the fact that the motions and impact loads on a planing hull decrease with decreasing hull trim angle (Ref. 1). Transom flap deflections, of course, reduce running trim angle.

Significant Bow Accelerations: Figure 14 shows that the significant bow accelerations (up) increase with increasing speed. Further, the magnitude of these accelerations decrease with increasing transom flap deflection. Again this follows from the lower hull trim angles associated with increasing transom flap deflection. As previously explained, the number of wave-hull impacts obtained in this exploratory study is not adequate to make a precise statistical evaluation of the effect of deadrise on impact loads. This will be determined in a subsequent detailed study of LVA seakeeping. However, with the test sample collected, it can be seen that there is some small difference between the inverted vee-bottom and the flat bottom hulls.

At 35 knots, the P-1 with chine flaps experienced a significant bow-up acceleration of approximately 1.6g with 12.5° transom flap deflection. For the same operating conditions, the flat bottom hull with chine flaps experienced 1.3g's. The P-1 without chine flaps encountered a significant bow acceleration of 1.25g with 7.5° transom flap.

Significant Center-of-Gravity Accelerations: Figure 15 presents plots of the significant center-of-gravity accelerations versus speed. The variations with speed, configuration, and transom flap deflection are essentially similar to those described for the bow accelerations. The magnitude of these C.G. impact accelerations are nearly one-half those at the bow. For instance, at 35 knots, the P-1 experienced a significant C.G. acceleration of 0.6g.

Significant Stern Accelerations: Figure 16 presents plots of the significant stern accelerations versus speed. Again, the stern accelerations increase with speed and decrease with increasing transom flap angle. The magnitude of these stern accelerations are nearly one-half those at the center of gravity. For instance, at 35 knots, the P-1 experienced a significant stern acceleration of only 0.25g for a transom flap setting of 12.5° and 0.32g for a transom flap setting of 7.5°.

Comparison of LVA Accelerations with Those for Other Planing Craft: In order to properly interpret the measured LVA accelerations, the significant accelerations at the C.G. are compared in Figure 20 with those for other planing hulls previously model-tested at the Davidson Laboratory. An envelope bounding the maximum and minimum values of LVA accelerations for all tested configurations is shown and compared with measured values for 6 other planing craft. These planing craft are identified only as to length, test sea state, and speed. It is seen that the LVA accelerations are well within the range of values for typical planing hulls. In fact, some of the comparison hulls experienced nearly twice the values of LVA center-of-gravity acceleration.

Estimate of Habitability in a Seaway: At the conclusion of the present rough water study, which generated data in a form which is conventional for planing hulls (i.e., statistics of motions and loads), it appeared to be useful to compare the measured impact accelerations with vibration exposure criteria of MIL-STD-1472A. It will be recalled that this criteria relates curves of

1/3-octave band rms "g" versus encounter frequency to levels of proficiency. Unfortunately, it was not convenient at that time to properly process the accelerations signals to generate such information. However, for the purposes of a "first look" at the tolerance levels, an engineering type analysis was made to recast the acceleration data into 1/3-octave band g's.

The engineering type analysis is admittedly not rigorous, but nevertheless is based on sufficiently applicable assumptions so as to adequately develop a "first evaluation" of tolerance levels. The following assumptions have been made.

1. The variance of the acceleration spectra can be divided into about three parts--i.e., there are only about three octave bands of significance. This is a conservative assumption since, if there are more third octave bands, the variance of a given third octave band would be a smaller portion of the total.

2. From (1) it then follows that the peak variance will be 1/3 the total variance observed for accelerations. Accordingly, the magnitude of an rms 1/3-octave band acceleration may conservatively be approximately $1/\sqrt{3}$ times the total rms acceleration.

3. An examination of the LVA model acceleration data indicates that the significant center-of-gravity accelerations quoted in this report are approximately 2.25 times the total rms. Accordingly, the magnitude of the 1/3-octave band accelerations may be $1/2.25\sqrt{3} \approx 1/4$ times the significant accelerations.

4. The center frequency is taken to be the number of acceleration maxima divided by the sample time. The assumption is that the result will be an estimate of the frequency position of the largest rms 1/3 band octave result.

The results of this simple analysis are shown in Figure 21. This figure is really two plots superimposed. The criteria from the MIL-STD are indicated for 1, 2.5 and 4 hours exposure time. The inner vertical scale pertains to the criteria. The outer vertical scale applies to significant accelerations for various planing craft, including the LVA, and are plotted against average encounter frequency. It is noted that the inner and outer scales differ by a factor of 4 so that, if the assumptions are reasonably correct, Figure 21 represents a comparison of acceleration levels achieved for various designs with the MIL-STD criteria.

It would not be entirely proper to conclude that the best of the LVA designs will meet the vertical vibration criteria at the center of gravity. However, it is proper to observe, from Figure 21, that the LVA is in the "ballpark". This was the purpose of the present simplified study. Future analysis of LVA acceleration data will be made using standard, consistant techniques.

Mean Effective Horsepower (EHP) in Waves: Figure 17 presents plots of the EHP versus speed for each of the three configurations tested in sea state 2. It is seen that the minimum test speed is 15 knots. At lower speeds, both the smooth water and rough water EHP were very small so that it was decided to concentrate on test speeds of 15 knots and greater.

For the most part, the smallest values of EHP were developed at the lowest test values of transom flap. It was observed that, as the transom flap was deflected in a seaway, the mean trim would decrease, the bow would contact the waves more frequently, and the mean resistance would increase. It would be well to investigate the effect of smaller than tested flap angles (even negative) on the rough water resistance.

A summary plot comparing the lowest values of resistance for each tested model is given in Figure 18. It is noted that, in general, the rough water EHP is essentially constant for speeds between 15 and 25 knots and then increases rapidly with increasing speed. The EHP for the P-1 without chine flaps is approximately 1110 hp in the 15 - 25 knot speed range. It decreases to 900 hp when chine flaps are added and is just over 800 hp for the flat bottom hull with chine flaps. At 30 knots, the rough water EHP is 1200, 980, and 940 for these three hulls.

Comparing these results with the smooth water resistance given in Figure 11, the following tabulation of rough water EHP increment (expressed as a percentage of smooth water EHP) is given:

Configuration	EHP Increment in Sea State 2 $V_K = 15$	$V_K = 25$	$V_K = 30$
P-1	38%	49%	64%
P-1 with Chine Flaps	28	58	75
Flat Bottom with Chine Flaps	33	58	77

These rough water EHP increments are larger than normally experienced with planing craft. Two features may contribute to this result. One is the relative blunt bow form associated with the LVA hull and the other is the small length of the craft relative to the mean wave length in a sea state 2. It is expected that "sharper" bow forms with less steep buttock lines at the lower aft end of the bow should reduce the rough water resistance. This should be further investigated.

Comparison of Measured and Predicted
Smooth Water EHP for 0^o Transom Flap

Analytical techniques for predicting smooth water performance of prismatic planing hulls are available (Ref. 3) but have not yet been compared with experimental data for heavily loaded hulls such as characterized by the present LVA. The data in this report offer an opportunity to make this comparison. Calculations were made for the P-1 and the flat bottom models with zero transom flap deflection and with and without the 3-ft. wide chine flaps. The inverted vee-bottom was assumed to have effective prismatic deadrise of 10^o. The partial span transom flap at zero degrees was accounted for in the calculations by assuming it to be a full span flap having a chord such that its area was equal to the area of the actual flap. Since the full-scale flap had an area of $6.5 \times 3 = 19.5 ft^2$, the "effective" flap used in the prismatic hull calculations had the following dimensions:

Hull Beam	Effective Flap Span	Effective Flap Chord
11' (No Chine Flaps)	11'	1.77'
17' (With 3' Chine Flaps)	17'	1.15'

Although hydrodynamic formulations for deflected flaps are presented in Ref. 2, they are not applied in the present study of the LVA since it has been found that further development is required to establish equilibrium conditions for a free-to-trim and free-to-heave flap-controlled planing hull. It is expected that this work will be undertaken in the subsequent phase of this development.

Figure 22 presents comparisons between calculated and measured EHP and equilibrium trim for the following four models--all with a 6.5' span by 3' chord transom flap at zero degree deflection (full scale).

1. P-1 - No Chine Flaps
2. P-1 - With Chine Flaps
3. Flat Bottom - No Chine Flaps
4. Flat Bottom - With Chine Flaps

The bare hull EHP and equilibrium trim have been calculated following the procedures of Ref. 3 and 4 and representing the transom flap as previously discussed. The vertical center of gravity is taken to be 3.5 ft. above the keel and the thrust line is parallel to and 1.25 ft. below the keel. It is seen that the agreement between calculated and measured hump values is within 5% for the hulls without chine flaps and within 9% for hulls with the 3' wide chine flaps. The agreement is considerably better at higher speeds.

CONCLUSIONS

Model tests of two planing hull concepts (an inverted vee-bottom and a flat bottom) for the LVA were conducted at a nominal, full-scale, gross weight of 55,000 lbs. and an LCG 12.5 ft. forward of the transom. The following conclusions are based on an analysis of the test results which were obtained over a range of test speeds from 10 to 40 knots.

Smooth Water

1. The hump trim of the craft occurs at approximately 15 knots planing speed.
2. The addition of transom flaps is effective in reducing the trim and EHP at hump speed.
3. Proper deflection of transom flaps provide trim control to enable the craft to plane at near optimum trim angle at speeds in excess of the hump speed.
4. The addition of retractable chine flaps is beneficial in reducing EHP and trim throughout the speed range.
5. Based on the present test data, procedures for optimum transom and chine flaps can be developed.
6. Porpoising occurs at speeds in excess of 30 knots, but is easily eliminated by small deflections of the transom flap.
7. For the zero flap deflection case, the computed and measured EHP and equilibrium trim are in good agreement.
8. The lift-drag ratio of the craft with chine and transom flaps is approximately 10 at 35 knots.

Rough Water

Model tests in a head sea state 2 lead to the following conclusions:

1. Pitch and heave oscillations decrease with decreasing trim angle.
2. Over a speed range between 15 and 3[illegible] knots, the pitch and heave motions are essentially independent of speed if, at each speed, the craft is properly trimmed by the transom flap.
3. The motions of the LVA are not unlike those of convential planing craft.

4. The impact accelerations decrease with decreasing trim angle, but increase with increasing speed.

5. Typically, the bow accelerations are nearly twice those at the center of gravity while the stern accelerations are nearly one-half those at the C.G.

6. The levels of impact acceleration are not unlike those of well-designed planing hulls.

7. Based on an elementary 1/3-octave band analysis, the rms g's at the center of gravity are within the 1 hour tolerance level as defined in MIL-STD-1472A.

8. The added EHP in waves is approximately 50% higher than the smooth water EHP. This is attributed to the blunt bow form and to the small size of the LVA relative to the waves in a state two sea. Improvements in bow form are recommended.

9. There is only a small difference in impact accelerations between the inverted vee bottoms and flat bottom hulls.

10. Further hull form development is recommended to reduce accelerations in a seaway.

ACKNOWLEDGEMENT

The authors would like to acknowledge the contribution of Mr. John K. Roper of Roper Associates to all aspects of this study and to Mr. John Dalzell in the analysis of rough water data. The constant encouragement of Mr. David Halper of Code 112 of NSRDC, who was technical coordinator, is also acknowledged.

REFERENCES

1. *Fridsma, Gerard: "A Systematic Study of the Rough Water Performance of Planing Boats, Irregular Waves - Part II" Davidson Laboratory, Stevens Institute of Technology Report 1495, March 1971*

2. *Brown, P.W.: "An Experimental and Theoretical Study of Planing Surfaces with Trim Flaps" Davidson Laboratory, Stevens Institute of Technology Report 1463, April 1971*

3. *Savitsky, Daniel: "Hydrodynamic Design of Planing Hulls" Marine Technology SNAME, Vol. 1, No. 1, October 1964*

4. *Blount, Donald L. and Fox, David L.: "Small Craft Power Prediction" Paper presented at Western Gulf Section of SNAME, 14 February 1975*

TABLE 1

LVA HULL P-1

Load 50,000 lb
LCG 12.5 ft fwd of transom

Trans. Flap deg	Speed kt	Drag lb	EHP	Trim deg	Heave ft	Wetted Length ft	Wetted Area sq ft
0	10.04	7080	216	2.4	- .8	25.0	418
0	14.98	17230	793	20.0	1.6	17.5	231
0	20.03	14560	896	15.9	2.7	14.0	174
0	25.02	11280	867	11.5	3.2	13.5	168
0	30.05	9180	847	8.5	3.3	13.0	162

TABLE 2

LVA HULL P-1

Load 55,000 lb
LCG 12.5 ft fwd of transom

Trans. Flap deg	Speed kt	Drag lb	EHP	Trim deg	Heave ft	Wetted Length ft	Wetted Area sq ft
0	10.04	2950	91	- .2	1.7	23.0	304
0	14.98	20900	962	22.0	1.9	16.5	274
0	19.97	17390	1067	17.5	3.1	14.5	179
0	25.00	13590	1044	12.4	3.5	13.5	168
0	30.05	11140	1028	9.2	3.5	13.5	168
5.0	35.06	7550	813	5.2	3.3	14.5	179
5.0	40.06	8850	1089	4.0	3.3	16.0	196
7.5	30.07	8370	773	6.3	3.2	16.0	196
7.5	35.06	6970	750	4.1	3.2	15.5	191
7.5	40.06	6630	816	2.8	3.1	17.0	208
10.0	35.06	6970	751	3.7	3.1	16.5	202
12.5	25.04	9970	767	7.5	3.0	17.5	213
12.5	30.05	7910	730	4.6	3.0	17.5	213
12.5	35.08	9750	1050	2.3	2.9	20.0	242
15.0	14.98	16940	779	15.2	1.4	20.5	362
15.0	20.03	12990	799	10.9	2.4	18.5	225

TABLE 3

LVA HULL P-1

Load 60,000 lb
LCG 12.5 ft fwd transom

Trans. Flap deg	Speed kt	Drag lb	EHP	Trim deg	Heave ft	Wetted Length ft	Wetted Area sq ft
0	10.04	8050	248	2.4	- 1.0	25.0	443
0	14.98	23180	1067	23.0	1.9	17.2	243
0	20.03	20070	1235	18.5	3.2	14.5	179
0	25.02	15080	1159	13.5	3.9	13.0	162
0	30.07	12050	1113	9.9	3.9	13.0	162
2.5	30.05	11220	1036	8.8	3.7	13.2	165
5.0	25.04	13490	1038	11.4	3.5	18.5	225
5.0	30.05	10490	968	7.9	3.6	14.5	179
5.0	35.06	8610	927	5.6	3.5	15.0	185
5.0	40.06	7566	931	4.1	3.5	-	-
7.5	30.05	9870	911	7.0	3.4	15.1	186
7.5	40.02	7340	903	3.1	3.4	16.5	202
10.0	25.02	12370	950	9.5	3.3	15.5	191
10.0	30.07	9200	850	5.9	3.3	16.5	202
10.0	35.06	7730	832	3.7	3.3	17.5	213
12.5	20.03	16550	1018	13.5	2.7	17.0	208
12.5	25.04	11260	866	8.2	3.2	17.0	208
12.5	30.05	8450	779	4.7	3.2	17.7	216
12.5	35.06	9760	1051	2.9	3.1	20.2	244
15.0	14.98	19630	903	16.0	1.4	20.5	357
15.0	20.03	15590	959	12.3	2.6	17.0	208

TABLE 4

LVA HULL P-1

Load 55,000 lb
LCG 13.5 ft fwd of transom

Trans. Flap deg	Speed kt	Drag lb	EHP	Trim deg	Heave ft	Wetted Length ft	Wetted Area sq ft
0	14.98	17970	827	18.7	1.8	19.5	331
0	20.03	16210	997	15.5	2.7	16.0	196
0	25.04	12480	959	11.5	3.5	14.0	174
0	30.05	10130	935	8.5	3.4	13.5	168
5.0	35.06	7680	825	4.9	3.1	16.0	196
5.0	40.02	6990	859	3.7	3.2	16.0	196
7.5	30.07	8350	771	5.9	3.1	17.0	208
7.5	35.06	7780	837	3.7	3.0	17.0	208
7.5	40.06	6940	854	2.8	3.1	17.5	213
10.0	35.06	7930	853	3.3	2.9	18.7	228
15.0	14.98	18140	835	10.9	0.8	21.5	369
15.0	20.03	15100	929	10.4	2.0	20.5	247

TABLE 5

LVA HULL P-1

Load 55,000 lb
LCG 12.5 ft fwd of transom
With Chine Flaps

Trans. Flap deg	Speed kt	Drag lb	EHP	Trim deg	Heave ft	Wetted Length ft	Wetted Area sq ft
0	14.98	18350	844	18.4	2.7	17.2	314
0	20.03	12570	774	12.2	3.5	13.2	244
0	25.04	9240	771	8.0	3.7	12.7	235
2.5	30.07	6690	618	4.7	3.5	13.5	249
5.0	30.07	6130	586	4.1	3.4	13.7	253
5.0	35.06	5800	624	2.7	3.3	12.5	231
5.0	40.06	5650	695	1.8	3.3	13.7	253
7.5	30.07	6100	564	3.4	3.3	15.0	275
7.5	35.06	5590	602	2.0	3.2	15.7	287
7.5	40.02	5770	710	1.1	3.2	17.0	310
12.5	25.04	7170	552	4.4	3.3	17.5	318
12.5	30.07	5810	536	2.1	3.2	17.7	322
15.0	14.98	14960	689	12.8	2.3	19.0	345
15.0	20.01	9770	603	7.5	2.9	17.2	314

TABLE 6

LVA FLAT BOTTOM HULL

Load 55,000 lb

LCG 12.5 ft fwd of transom

Trans. Flap deg	Speed kt	Drag lb	EHP	Trim deg	Heave ft	Wetted Length ft	Wetted Area sq ft
0	10.06	6060	187	4.4	- .1	23.5	354
0	14.98	18160	836	21.3	1.9	17.5	280
0	20.03	16320	1004	16.8	2.7	15.5	188
0	25.02	11670	897	11.9	3.3	13.7	164
2.5	35.06	7180	773	5.4	3.1	14.7	180
2.5	40.02	6800	836	4.1	3.1	15.2	185
5.0	35.06	6735	725	4.5	3.0	16.5	199
5.0	40.06	6690	823	3.2	3.0	17.2	208
7.5	30.05	7640	705	5.6	3.0	17.5	210
7.5	35.06	6710	722	3.5	2.9	19.5	232
10.0	25.02	9940	764	7.9	2.8	17.7	213
10.0	30.07	7920	731	4.7	2.8	20.0	238
12.5	20.03	12810	788	11.2	2.3	18.5	219
12.5	25.02	9530	732	6.6	2.7	20.0	238
15.0	14.98	16250	748	13.6	1.3	20.5	345
15.0	20.03	12830	789	10.2	2.2	20.0	238

TABLE 7

LVA FLAT BOTTOM HULL

Load 55,000 lb
LCG 12.5-ft fwd of transom
With Chine Flaps

Trans. Flap deg	Speed kt	Drag lb	EHP	Trim deg	Heave ft	Wetted Length ft	Wetted Area sq ft
0	14.98	17300	796	17.4	2.5	16.5	298
0	20.01	10680	656	10.9	3.2	15.0	273
0	25.04	7960	612	7.4	3.5	14.0	256
0	30.05	6170	569	5.0	3.4	13.5	247
2.5	30.07	6080	562	4.3	3.3	14.0	256
2.5	35.06	5450	587	3.0	3.2	14.2	260
2.5	40.06	5520	679	2.1	3.2	15.0	273
5.0	30.05	5870	541	3.7	3.3	15.0	273
5.0	35.06	5340	575	2.4	3.2	16.2	294
5.0	40.06	5790	712	1.5	3.1	17.5	3.5
7.5	30.05	5770	533	3.0	3.2	17.0	307
7.5	35.06	5760	620	1.7	3.1	18.7	337
12.5	25.02	6780	521	4.0	3.1	18.2	328
15.0	14.98	14240	655	12.9	2.4	19.0	341
	14.98	13800	635	12.3	2.2	19.5	345
15.0	20.03	8850	545	6.9	2.9	17.5	315

TABLE 8

LVA HULL

LCG - 12.5 ft Displacement - 55,000 lbs

Sea State 2

Transom Flap Angle deg	V kts	EHP	Mean Pitch deg	Heave ft	Significant Acceleration Stern Up g	Significant Acceleration CG Up g	Significant Acceleration Bow Up g	Significant Oscillation Pitch Up deg	Significant Oscillation Pitch Down deg	Significant Oscillation Heave Up ft	Significant Oscillation Heave Down ft
LVA HULL P-1											
0	15	1140	16.2	0.05	0.06	0.16	0.53	2.5	2.5	0.71	0.75
0	20	1260	16.7	2.30	0.11	0.34	0.71	3.8	3.9	0.85	0.80
0	25	1210	12.7	3.33	0.24	0.52	1.24	5.4	5.8	1.13	1.10
5.0	35	1510	6.1	3.38	0.35	0.75	1.83	5.7	6.2	1.49	1.31
7.5	30	1240	6.6	3.07	0.23	-	1.61	4.1	4.8	1.03	0.97
7.5	35	1490	5.5	3.22	0.33	0.74	1.28	4.6	5.3	1.11	0.93
10.0	25	1130	8.6	2.72	0.24	0.44	0.93	3.5	3.3	0.76	0.73
10.0	30	1460	5.8	2.86	0.26	0.48	1.28	3.3	3.5	0.90	0.88
12.5	25	1270	7.6	2.54	0.01	0.42	2.05	3.1	3.2	0.70	0.69
12.5	30	1660	4.8	2.64	0.20	-	1.24	2.7	3.1	0.75	0.72
12.5	35	2590	3.1	2.60	0.26	0.59	1.48	2.5	2.5	0.66	0.59
LVA HULL P-1 WITH CHINE FLAPS											
0	15	890	16.0	1.92	0.08	0.33	0.75	3.2	3.6	0.98	0.83
0	20	880	12.0	3.31	0.21	0.61	1.51	4.8	5.7	1.04	1.06
0	25	885	8.2	3.60	0.27	0.78	2.07	5.9	7.0	1.38	1.27
5.0	30	1040	4.7	3.44	0.34	0.82	1.99	3.7	4.9	1.26	1.11
5.0	35	1380	3.6	3.37	0.36	0.85	1.87	4.2	4.4	1.23	1.12
5.0	40	1800	3.6	3.62	0.52	-	2.26	4.3	4.2	1.71	1.10
7.5	30	1160	4.0	3.25	0.27	0.70	1.76	3.3	4.3	1.14	0.99
7.5	35	1910	2.9	3.07	0.34	0.66	1.66	3.3	3.9	1.21	0.92
7.5	40	3120	2.4	2.92	-	-	1.55	3.7	3.9	1.18	0.97
12.5	25	940	4.7	3.00	0.18	0.49	1.21	2.7	3.7	0.86	0.72
12.5	30	1780	2.6	2.74	0.23	0.41	0.86	2.3	2.6	0.79	0.61
LVA FLAT BOTTOM HULL											
0	15	870	15.6	2.11	0.11	0.33	0.69	3.1	3.4	0.86	0.89
0	20	810	11.1	3.21	0.20	0.61	1.56	4.9	5.3	1.06	0.94
0	25	870	7.5	3.82	0.30	0.88	2.20	5.7	6.7	1.37	1.13
2.5	30	1030	4.7	3.50	0.33	0.82	2.11	4.2	5.4	1.34	1.08
2.5	35	1340	3.5	3.55	0.39	0.89	1.94	4.1	4.5	1.33	0.94
5.0	30	1050	4.0	3.45	0.31	0.70	1.72	3.8	4.5	1.14	0.89
5.0	35	1470	2.9	3.29	0.36	0.81	1.70	2.9	4.0	1.01	0.89
7.5	30	1220	3.4	3.24	-	0.61	1.41	2.9	4.5	0.90	0.83
7.5	35	1830	2.0	3.14	0.34	0.59	1.25	2.4	3.1	0.75	0.77
12.5	25	860	5.3	3.32	0.25	0.65	1.61	3.9	4.4	1.01	0.85
15.0	15	980	7.4	0.62	0.07	0.19	0.34	2.1	2.1	0.57	0.62
15.0	20	830	6.2	2.51	0.25	0.38	0.79	2.5	2.9	0.65	0.70

*Oscillation about mean value.

TABLE 9

LVA HULL

LCG - 12.5 ft Displacement - 55,000 lbs

Transon .lap Angle deg	V kts	SEA STATE 2 MEAN EHP P-1 No Chine Flaps	SEA STATE 2 MEAN EHP P-1 With Chine Flaps	SEA STATE 2 MEAN EHP Flat Bottom Hull with Chine Flaps	SEA STATE 2 MEAN PITCH, deg. P-1 No Chine Flaps	SEA STATE 2 MEAN PITCH, deg. P-1 With Chine Flaps	SEA STATE 2 MEAN PITCH, deg. Flat Bottom Hull with Chine Flaps	SMOOTH WATER TRIM, deg. P-1 No Chine Flaps	SMOOTH WATER TRIM, deg. P-1 With Chine Flaps	SMOOTH WATER TRIM, deg. Flat Bottom Hull with Chine Flaps
0	15	1140	890	870	16.2	16.0	15.6	22.0	18.4	17.4
0	20	1260	880	810	16.7	12.0	11.1	17.5	12.2	10.9
0	25	1210	890	870	12.7	8.2	7.5	12.4	8.0	7.4
2.5	30	-	-	1030	-	-	4.7	-	4.7	4.3
2.5	35	-	-	1340	-	-	3.5	-	-	3.0
5.0	30	-	1040	1050	-	4.7	4.0	-	4.1	3.7
5.0	35	1510	1380	1470	6.1	3.6	2.9	5.2	2.7	2.4
5.0	40	-	1800	-	-	3.6	-	4.0	1.8	1.5
7.5	30	1240	1160	1220	6.6	4.0	3.4	6.3	3.4	3.0
7.5	35	1490	1910	1830	6.5	2.9	2.0	-	2.0	1.7
7.5	40	-	3120	-	-	2.4	-	2.8	1.1	-
10.0	25	1130	-	-	8.6	-	-	-	-	-
10.0	30	1460	-	-	5.8	-	-	-	-	-
12.5	25	1270	940	860	7.6	4.7	5.3	7.5	4.4	4.0
12.5	30	1660	1780	-	4.8	2.6	-	4.6	2.1	-
12.5	35	2590	-	-	3.1	-	-	2.3	-	-
15.0	15	-	-	980	-	-	7.4	15.2	12.8	12.6
15.0	20	-	-	890	-	-	6.2	10.9	7.5	6.9

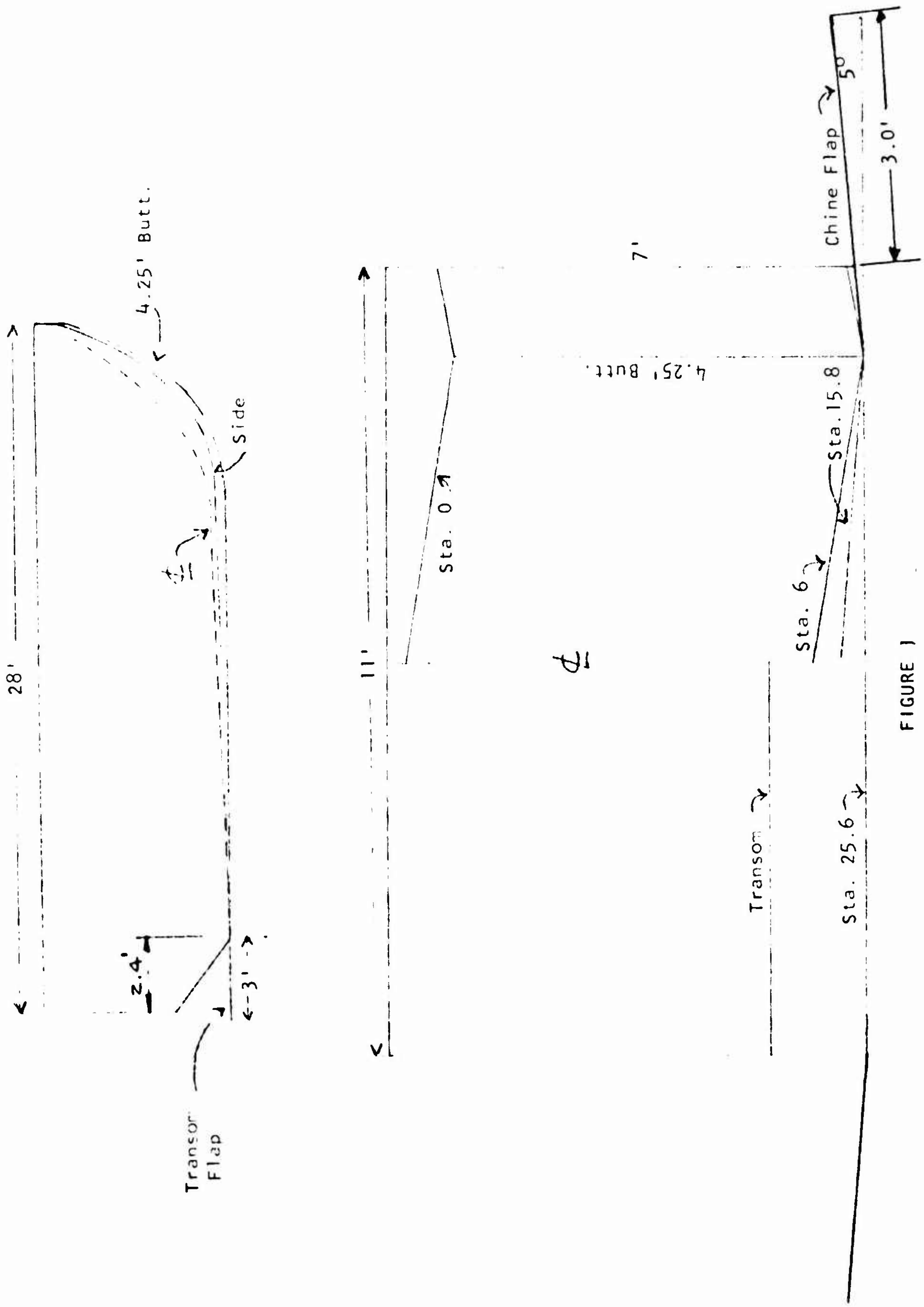


FIGURE 1
LVA Hull P-1

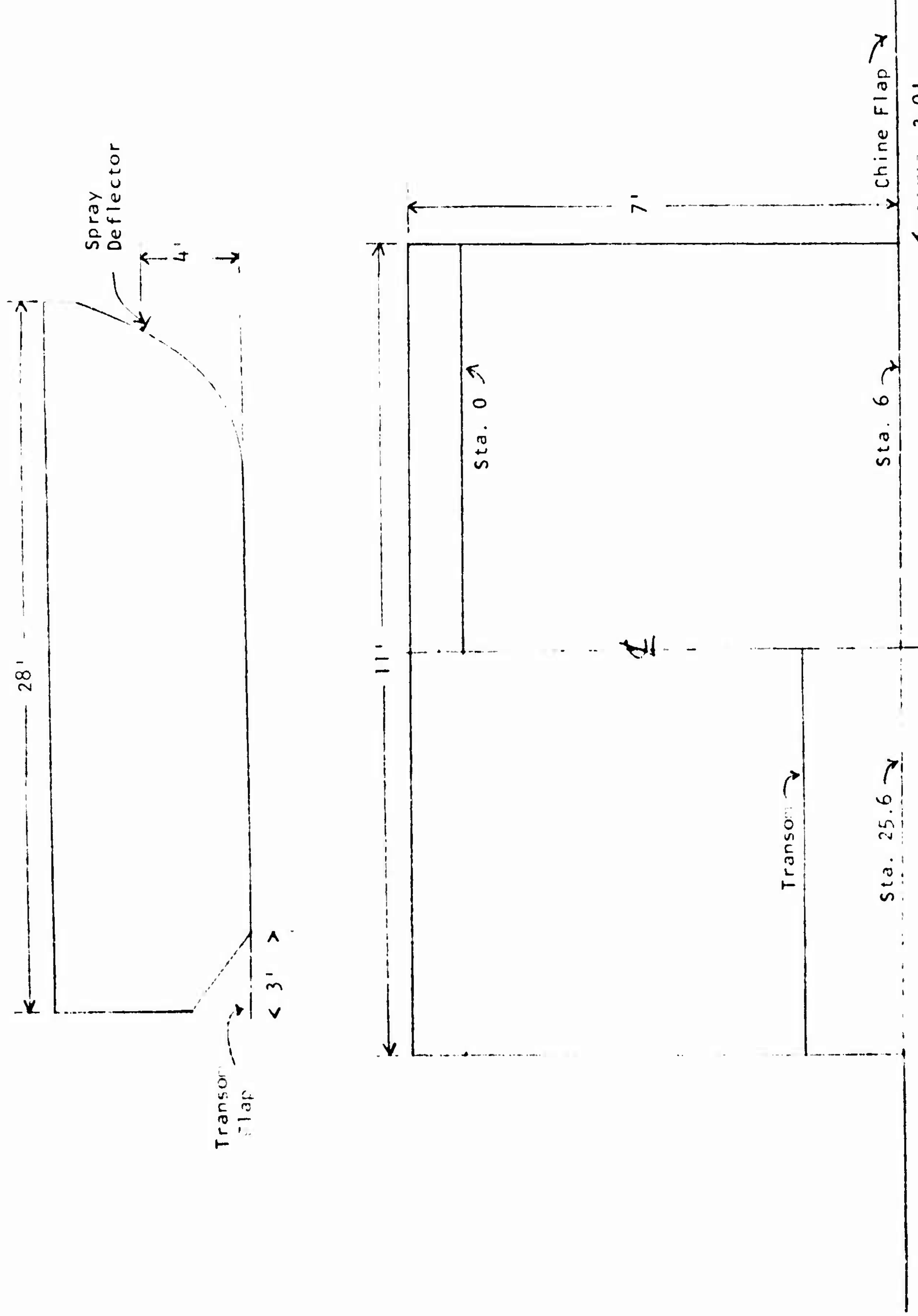


FIGURE 2
LVA FLAT BOTTOM HULL

LVA HULL

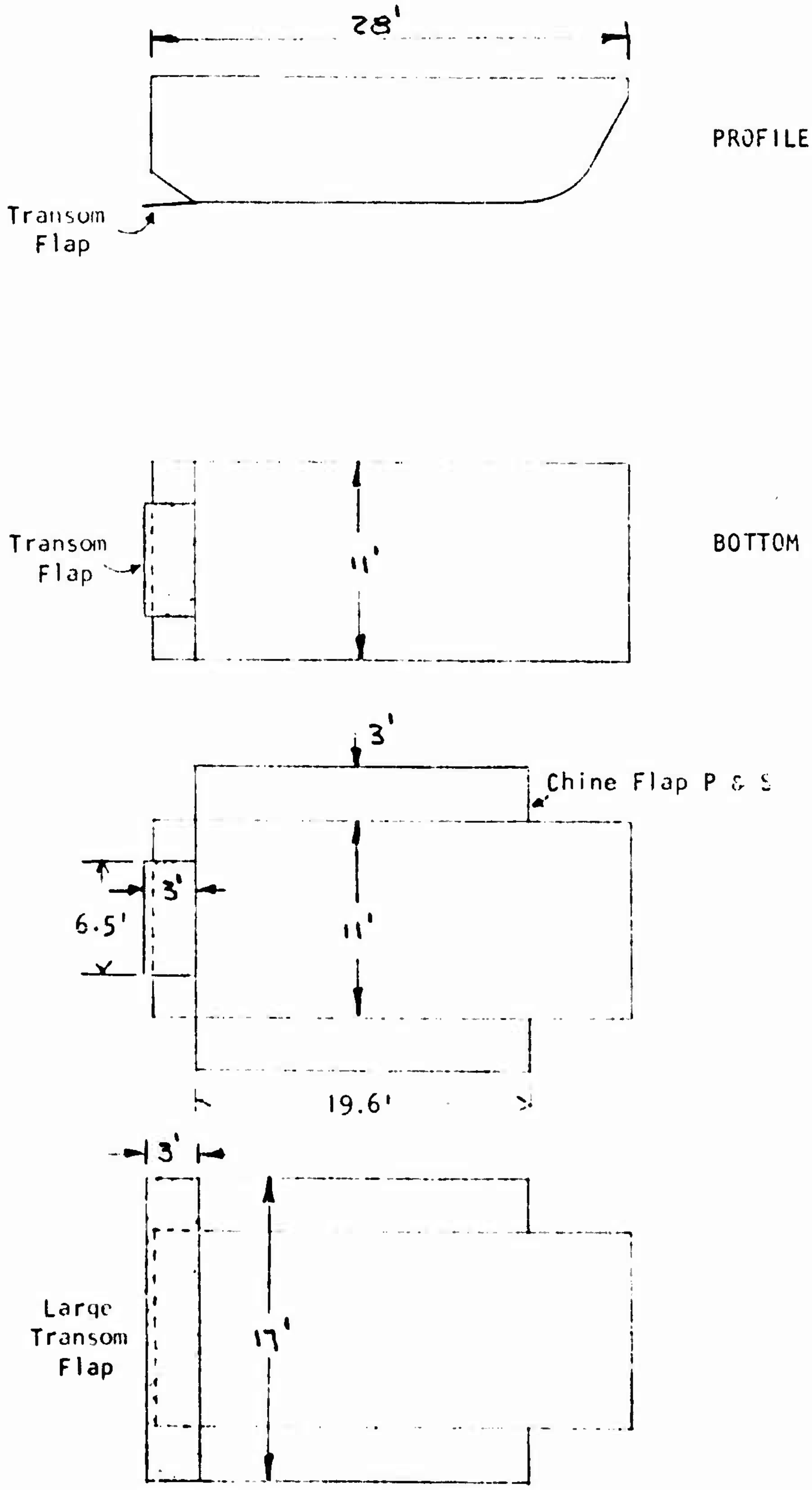


FIGURE 3

FIGURE 4
LVA HULL P-1

50,000 lb 12.5 ft LCG

SMOOTH WATER

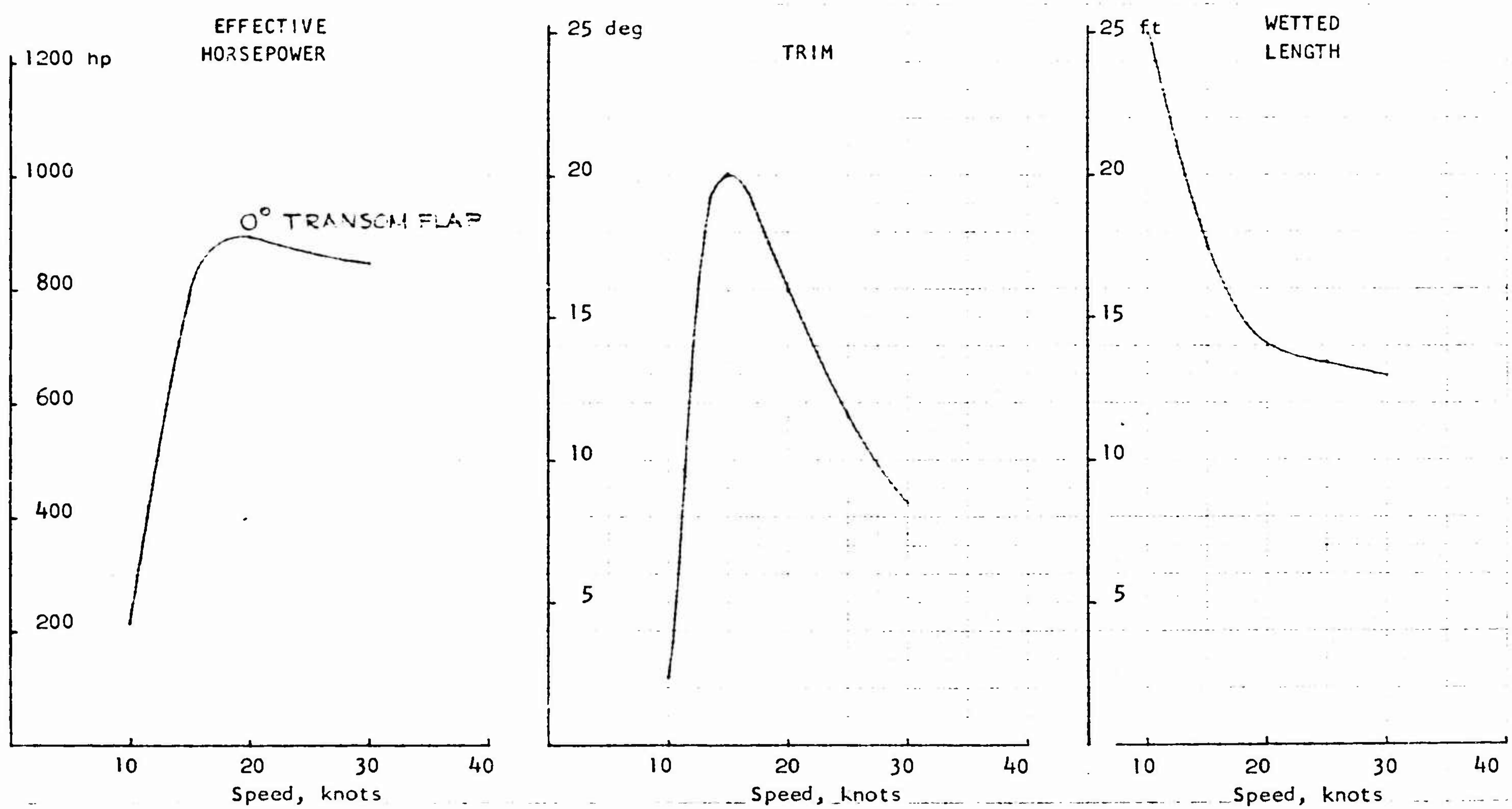


FIGURE 5
LVA HULL P-1

55,000 lb 12.5 ft LCG

SMOOTH WATER

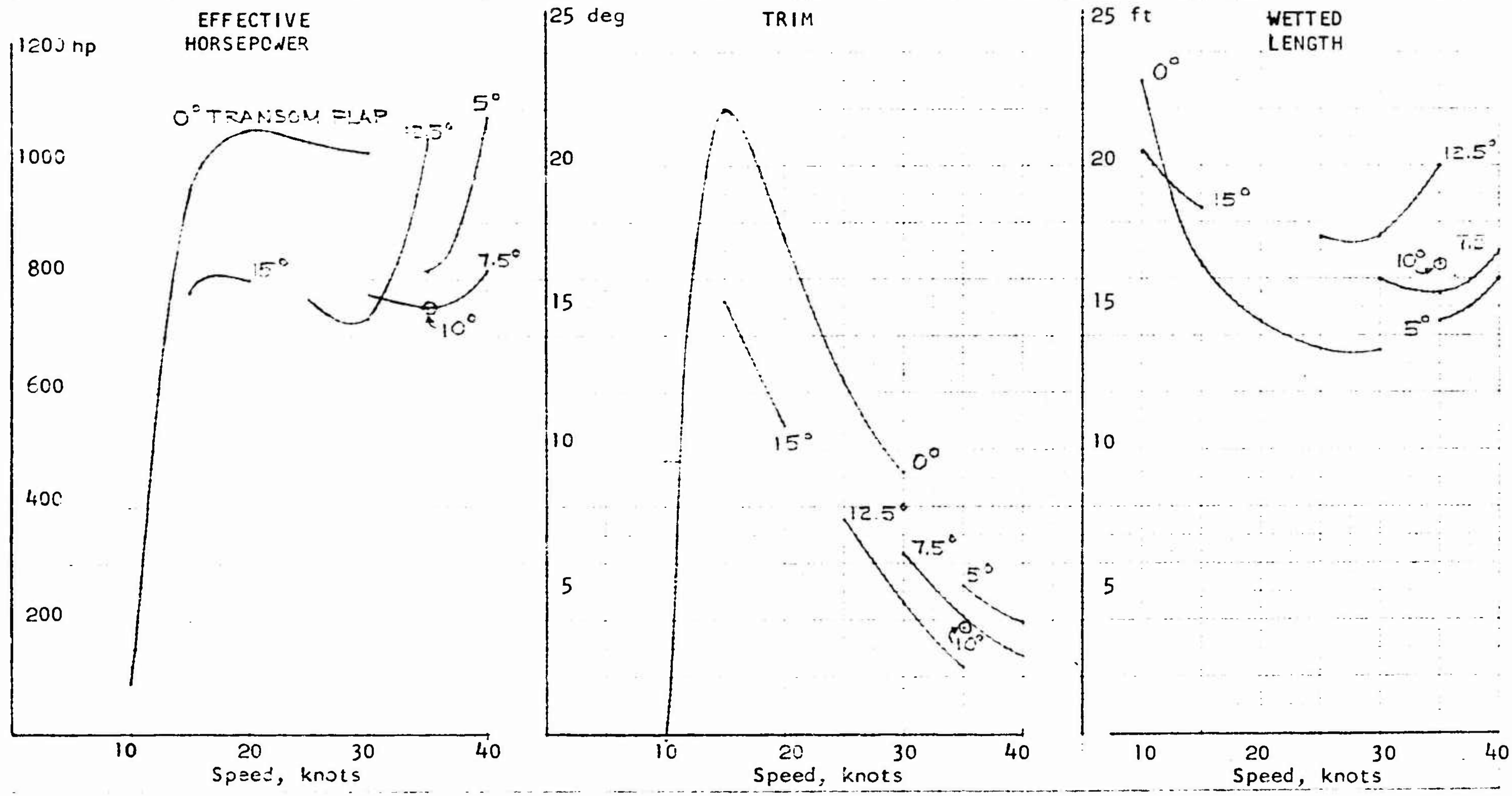


FIGURE 6

LVA HULL P-1

60,000 lb 12.5 ft LCG

SMOOTH WATER

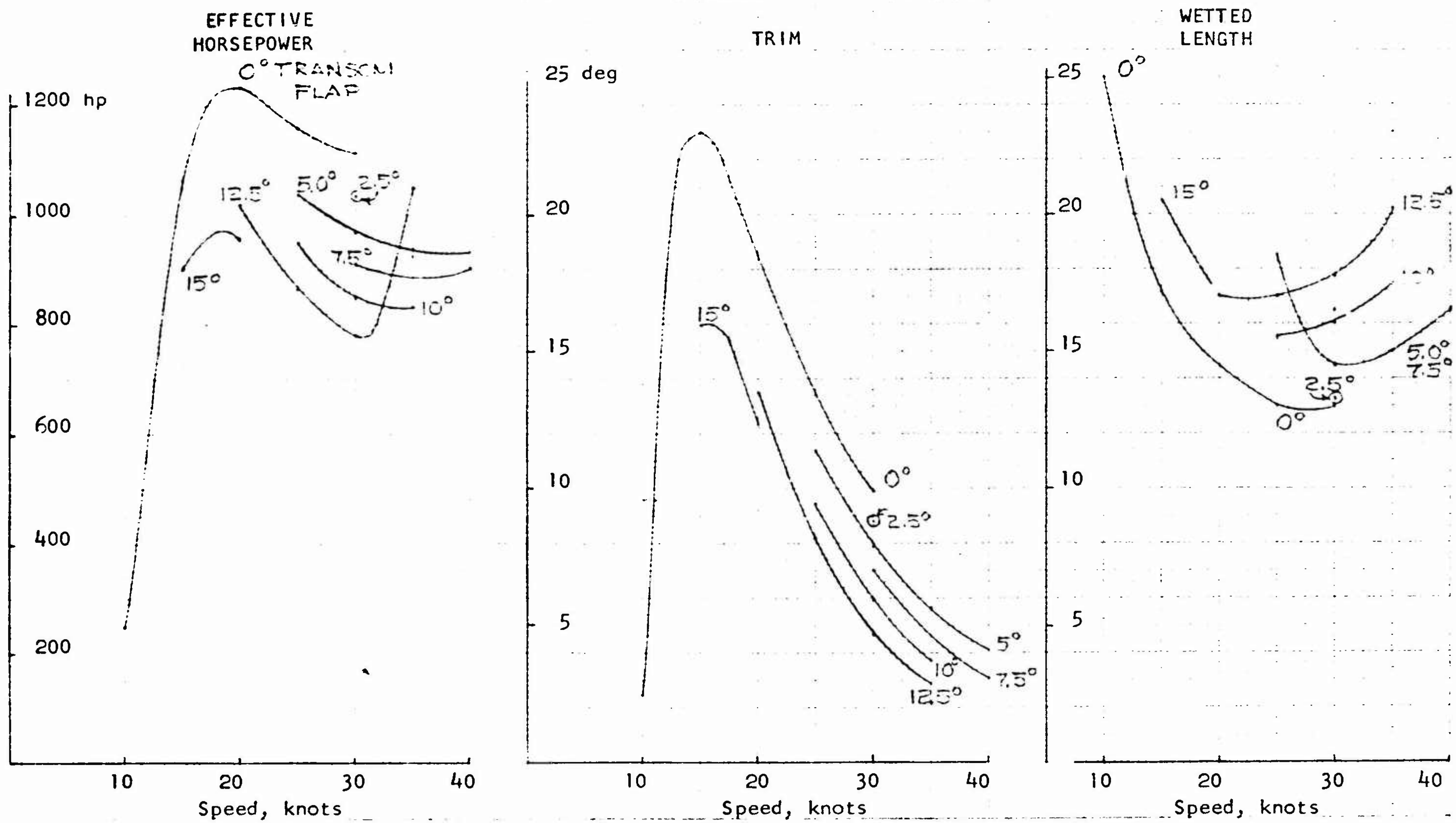


FIGURE 7
LVA HULL P-1

55,000 lb   13.5 ft LCG

SMOOTH WATER

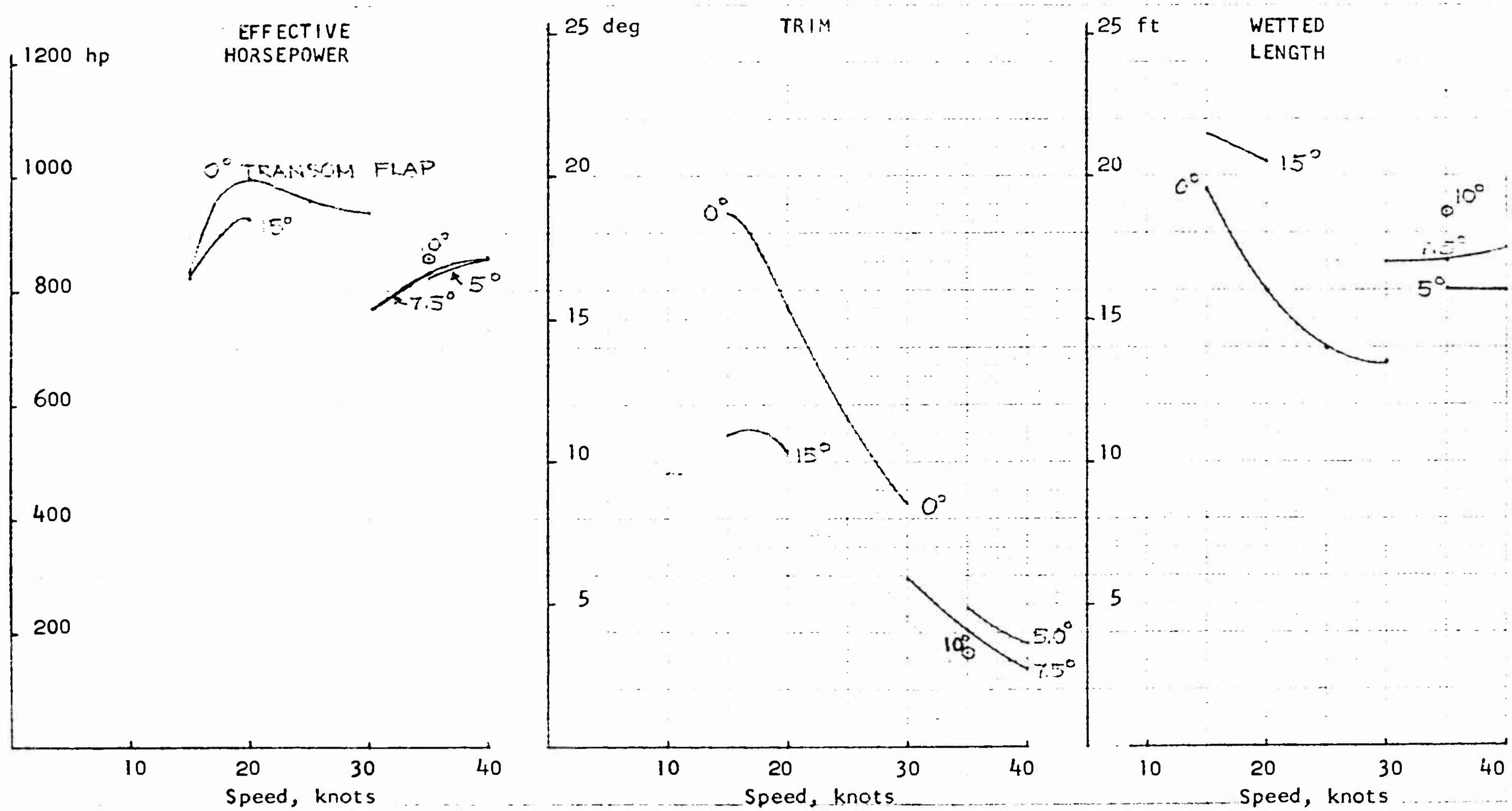


FIGURE 8

LVA HULL P-1

55,000 lb 12.5 ft LCG

WITH CHINE FLAPS

SMOOTH WATER

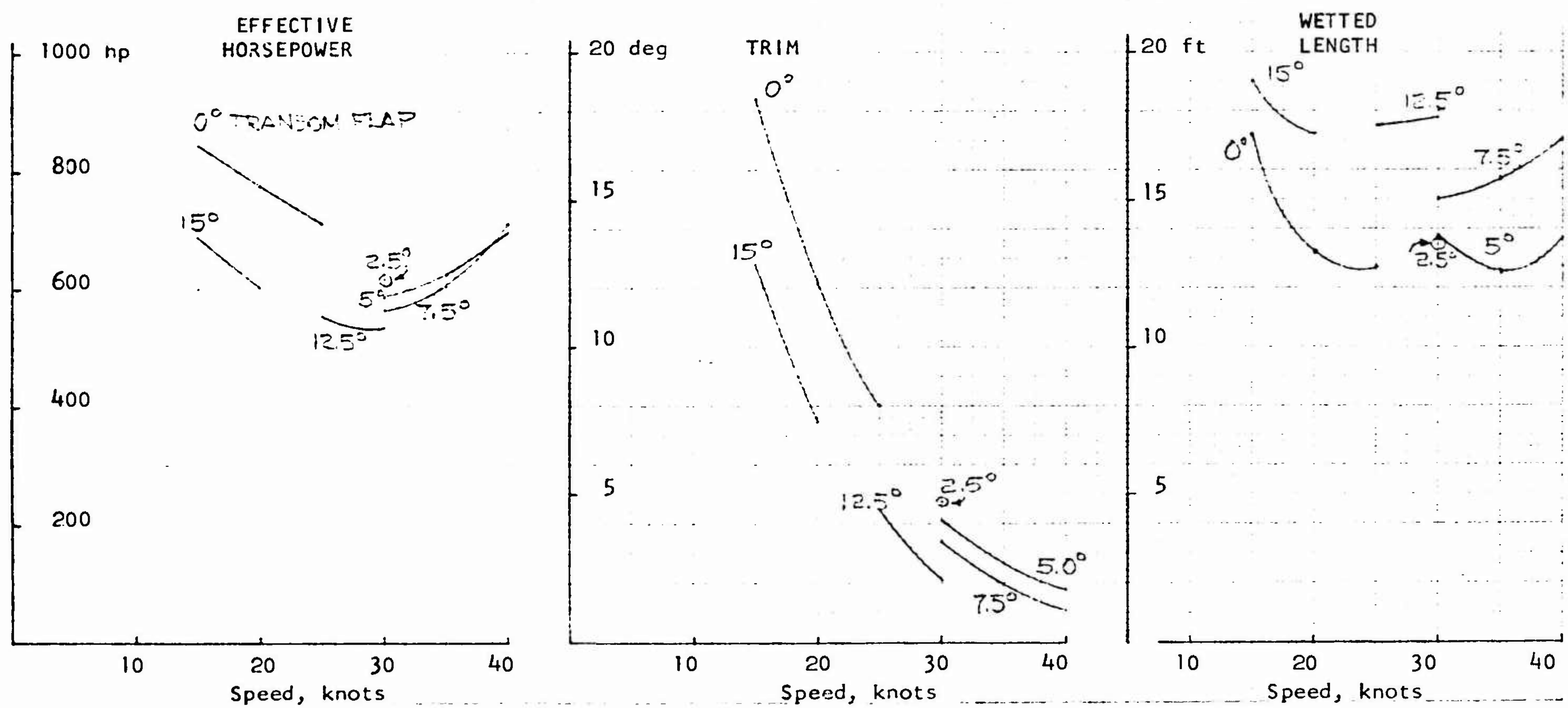


FIGURE 9
LVA FLAT BOTTOM HULL

55,000 lb   12.5 ft LCG

SMOOTH WATER

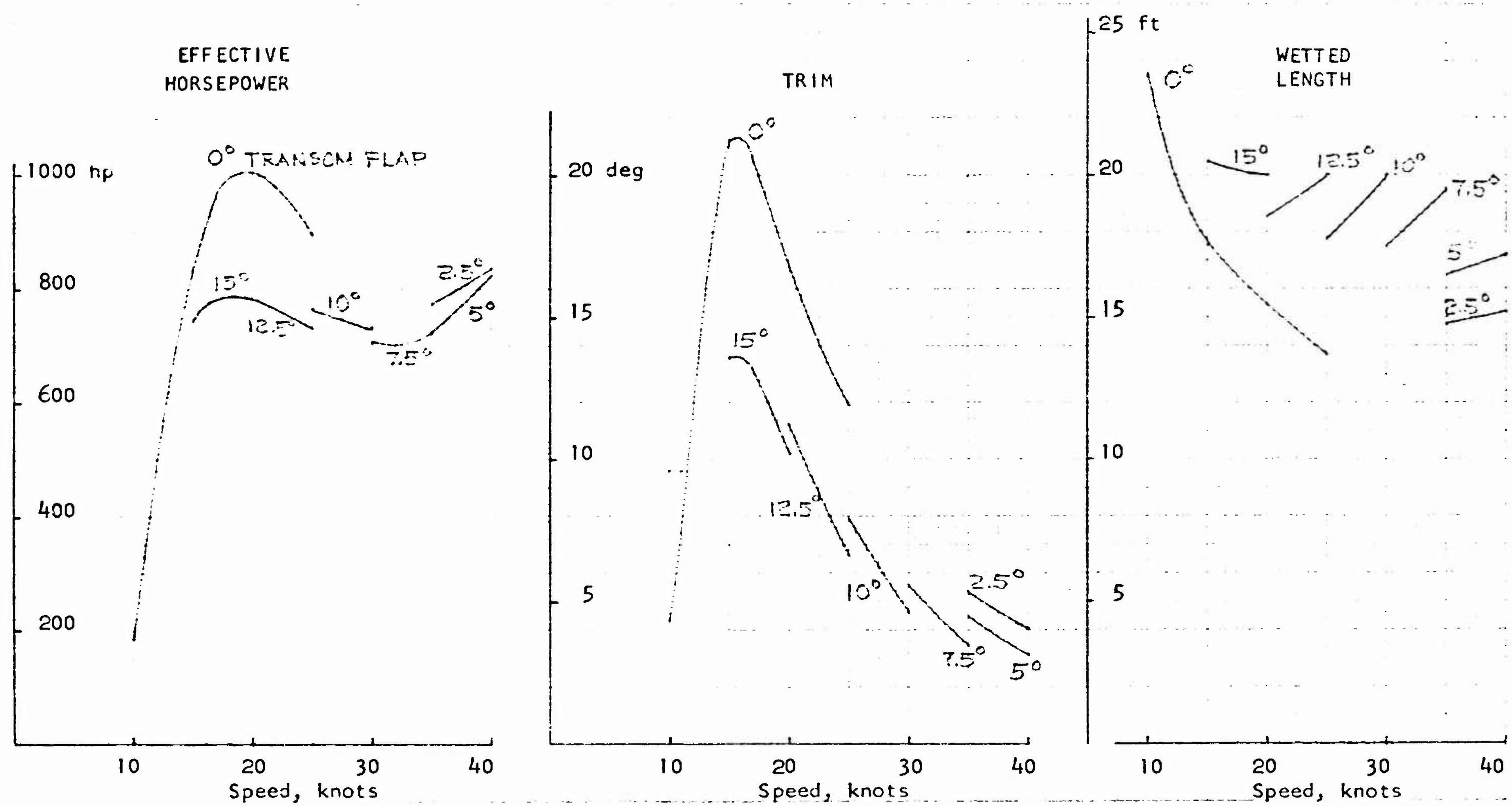
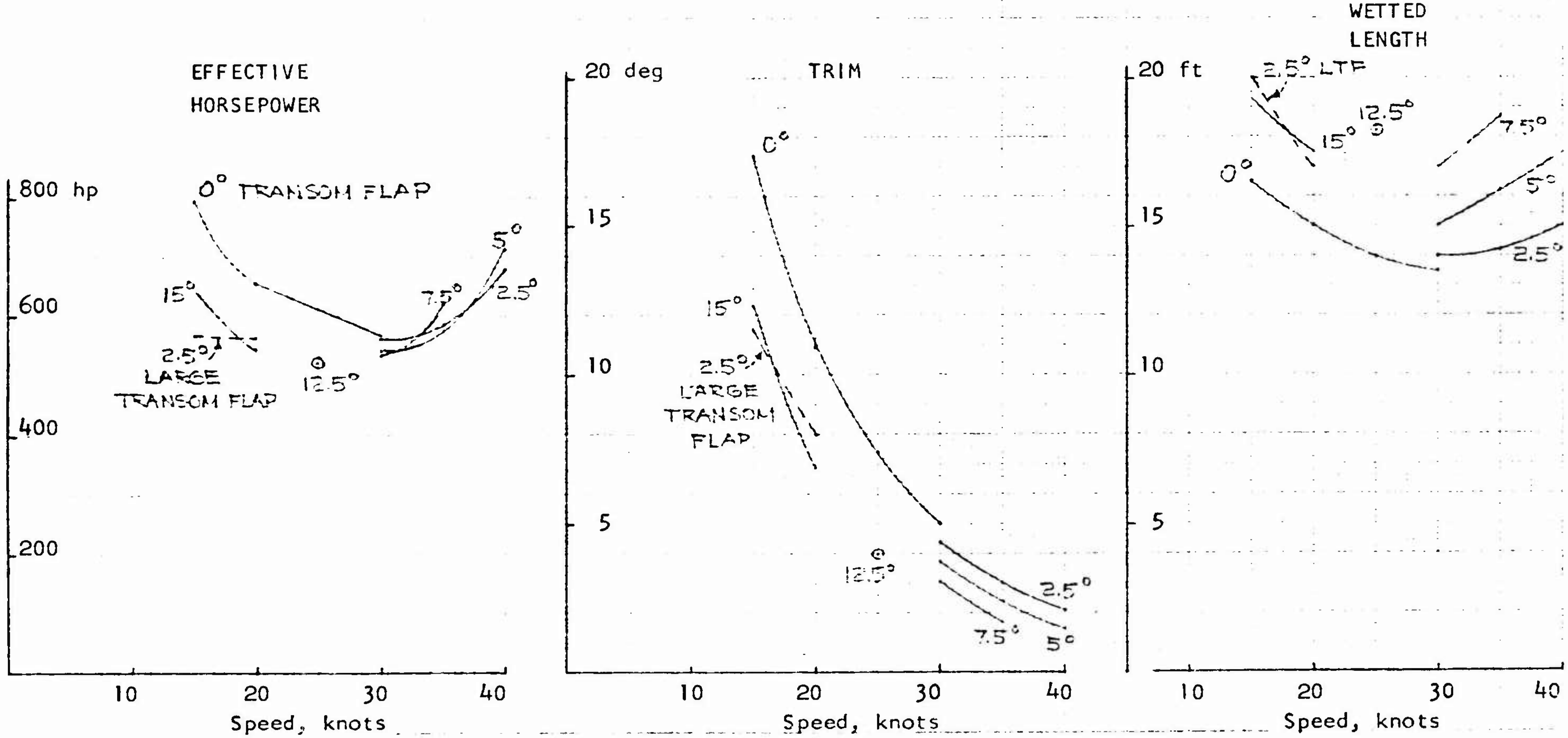


FIGURE 10
LVA FLAT BOTTOM HULL

55,000 lb 12.5 ft LCG

WITH CHINE FLAPS

SMOOTH WATER



SMOOTH WATER

EHP AND TRIM VERSUS SPEED

Δ = 55,000 lbs. LCG = 12.5' F'W'D TRANSOM

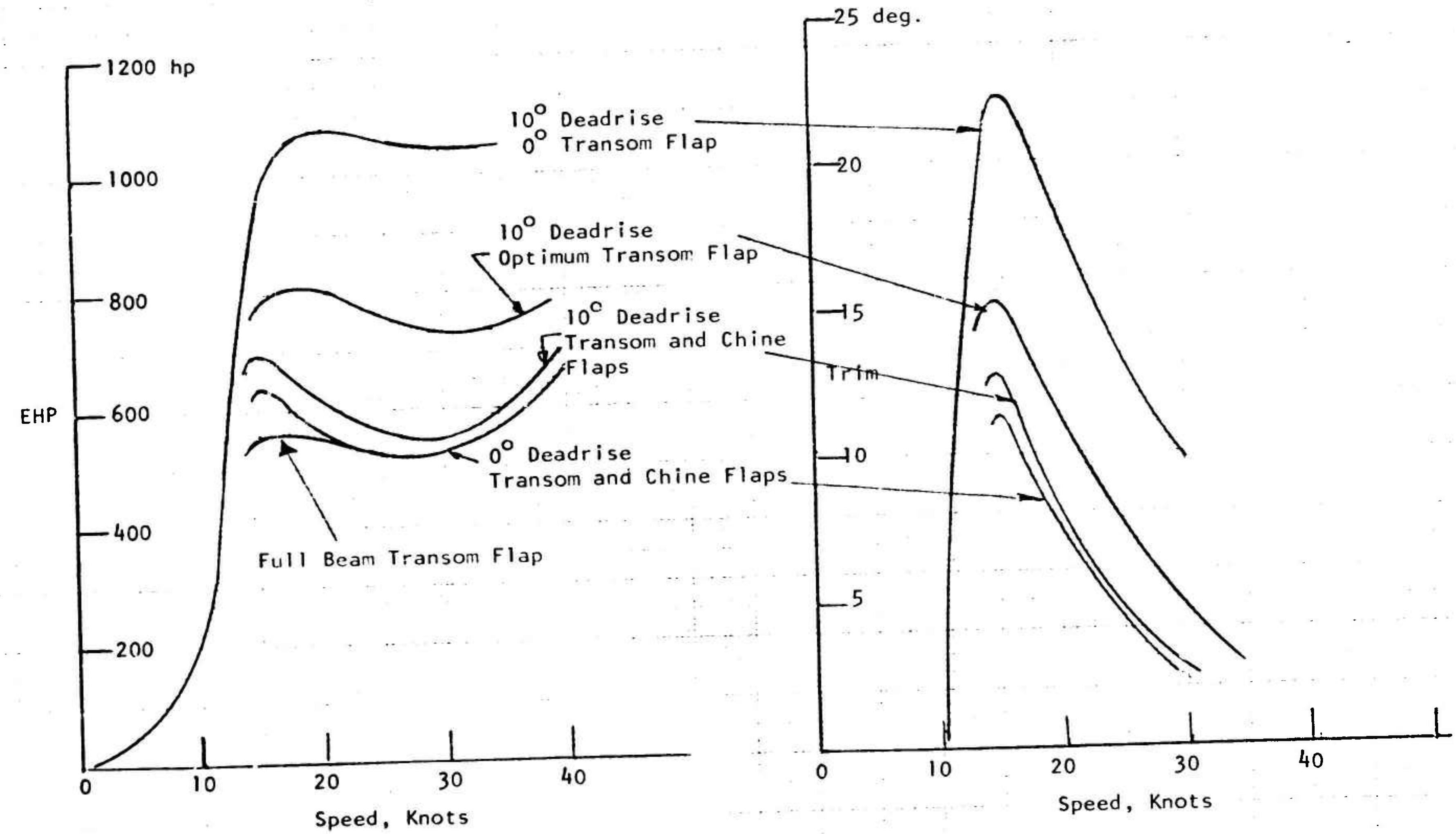


FIGURE 11

FIGURE 12
SIGNIFICANT PITCH
VS
SPEED

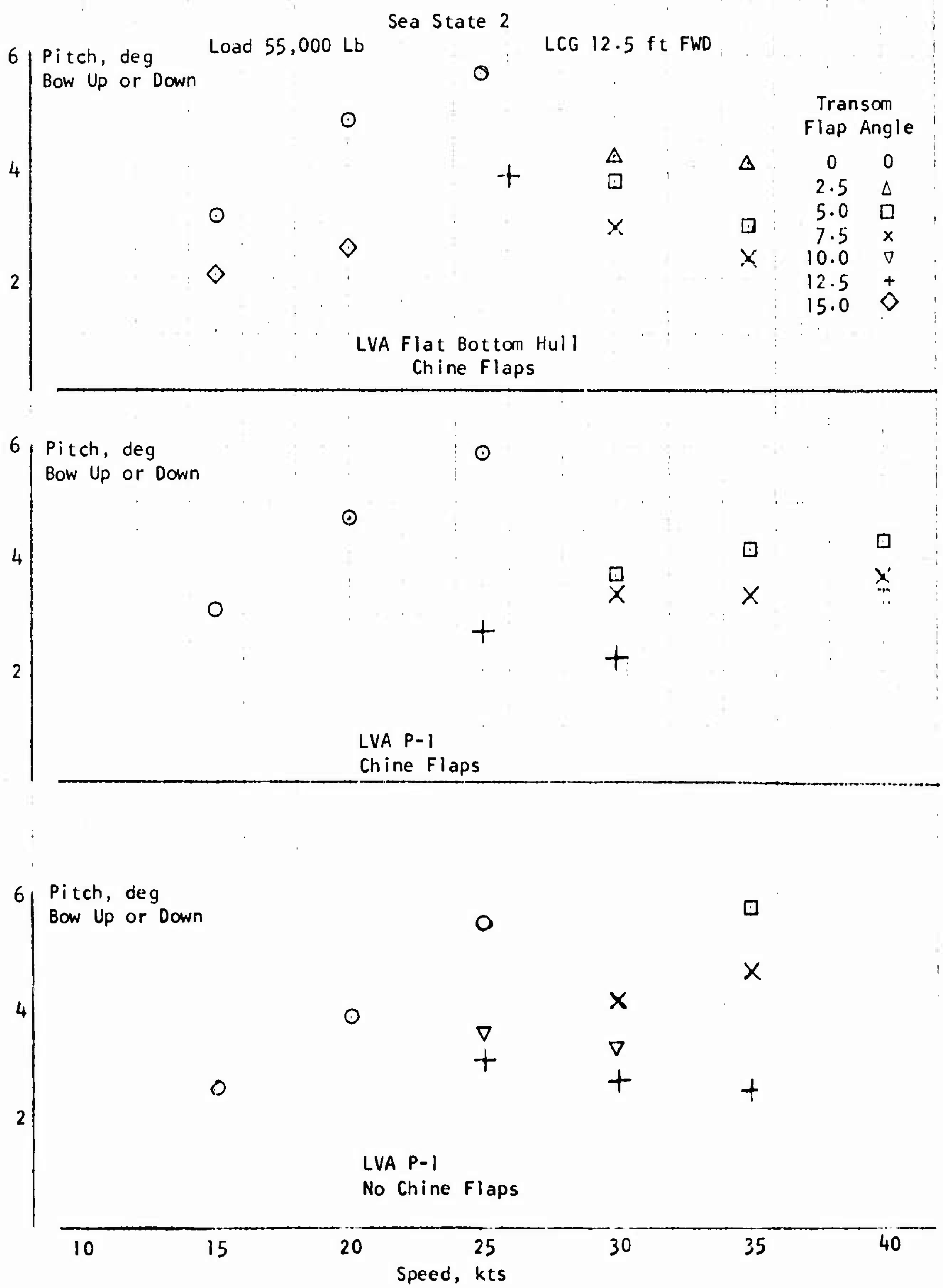


FIGURE 13
SIGNIFICANT HEAVE
VS
SPEED

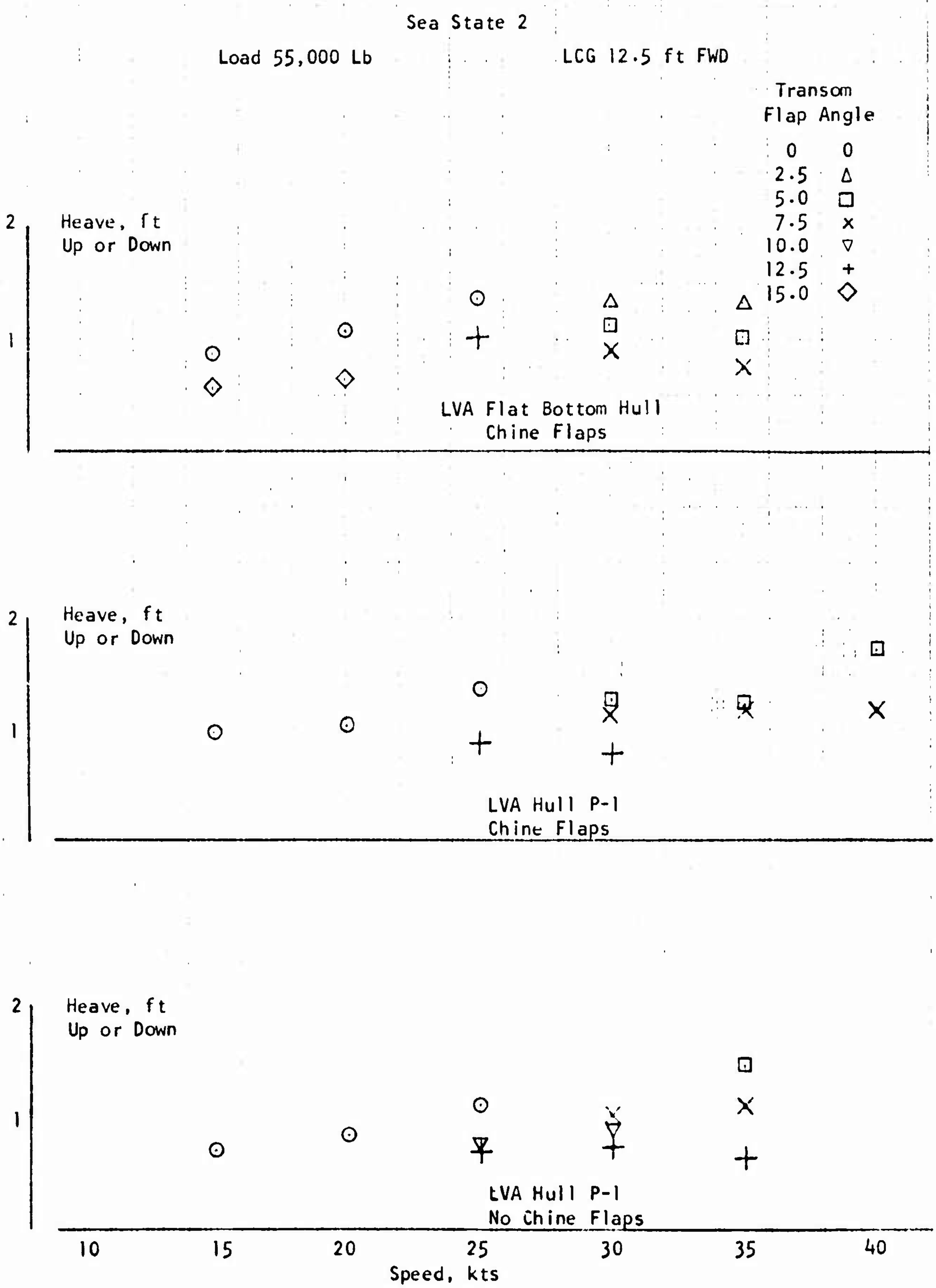


FIGURE 14
SIGNIFICANT BOW ACCELERATION
VS
SPEED

SEA STATE 2

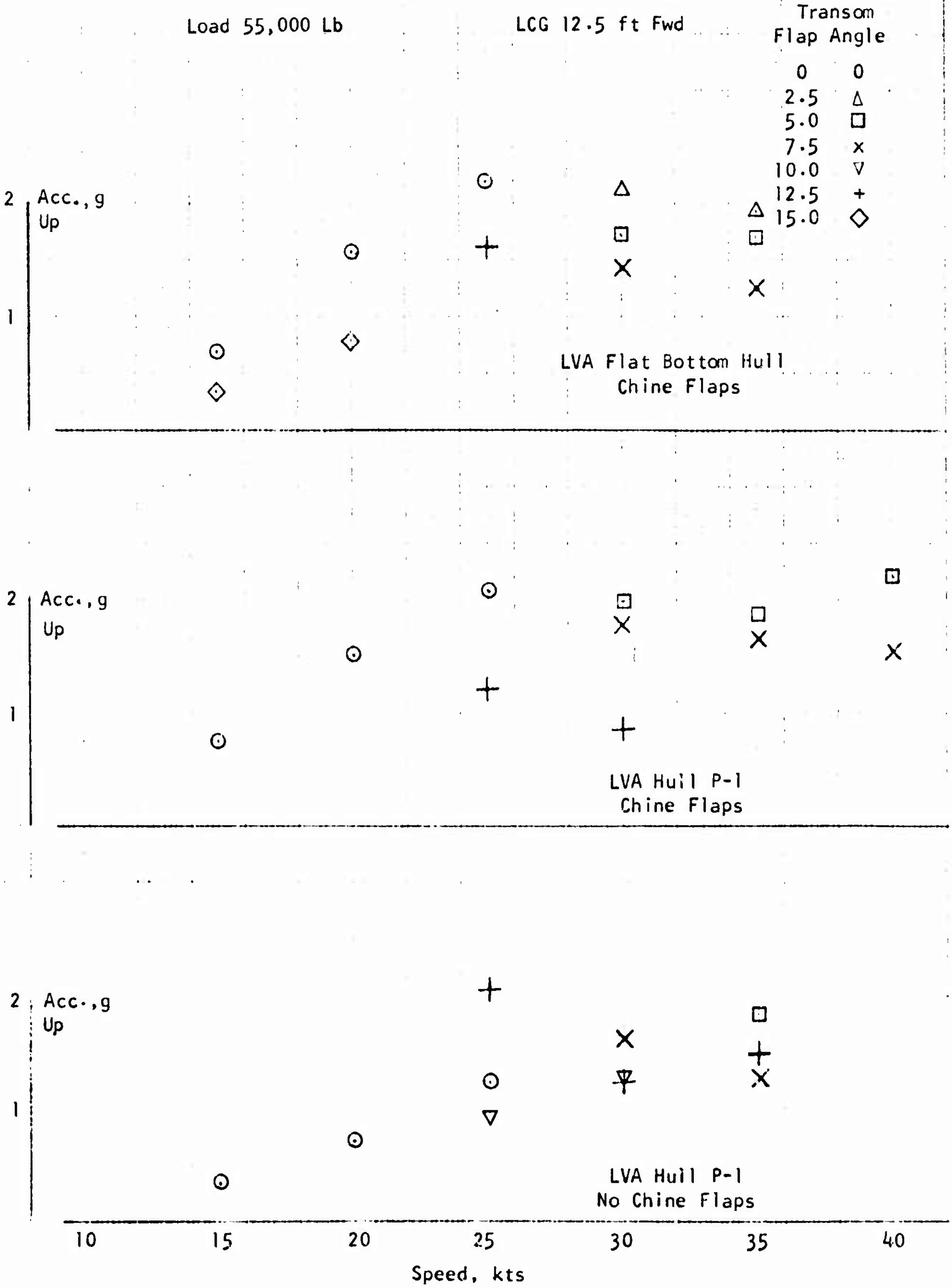


FIGURE 15

SIGNIFICANT C.G. ACCELERATION
VS
SPEED

SEA STATE 2

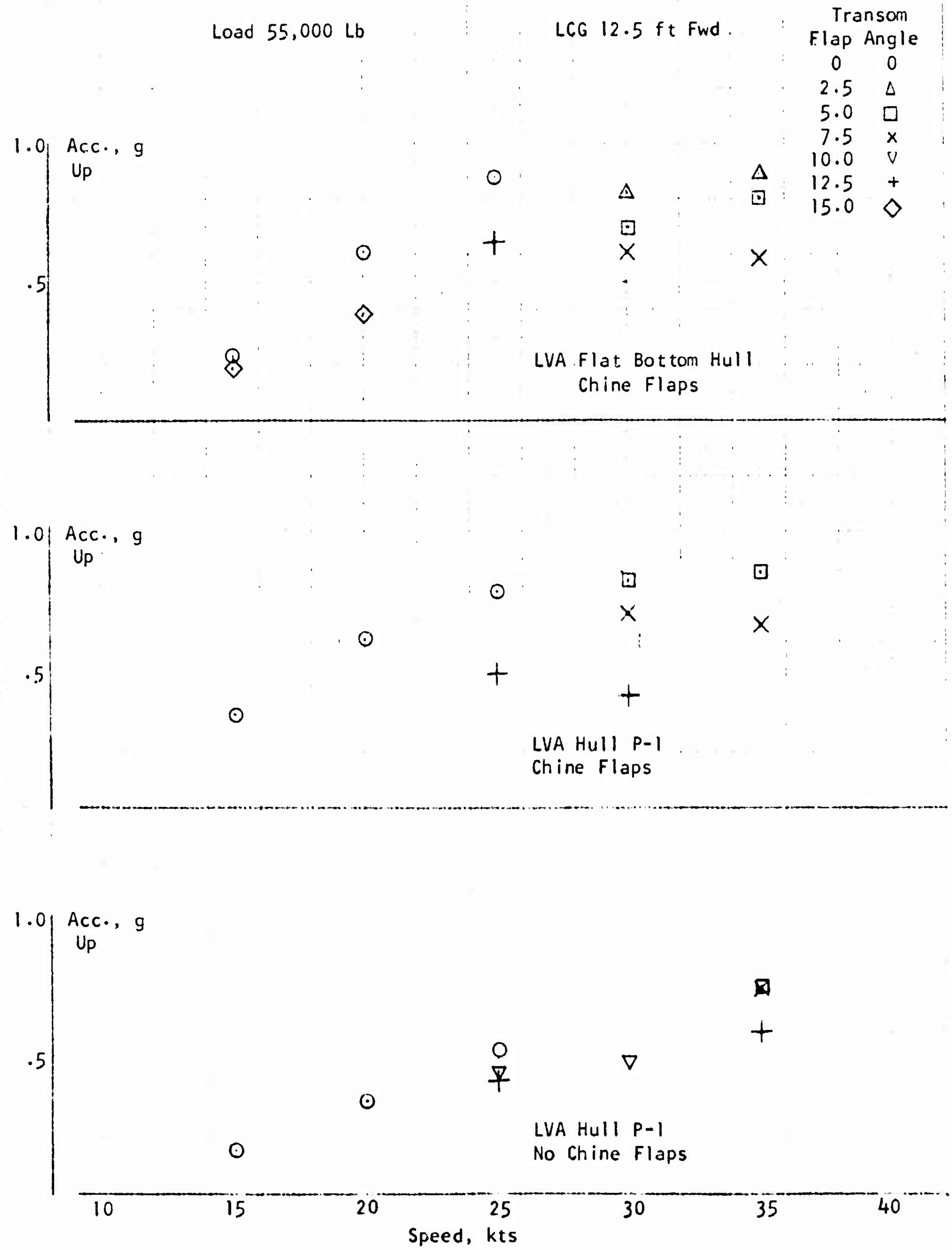


FIGURE 16

SIGNIFICANT STERN ACCELERATION
VS
SPEED

SEA STATE 2

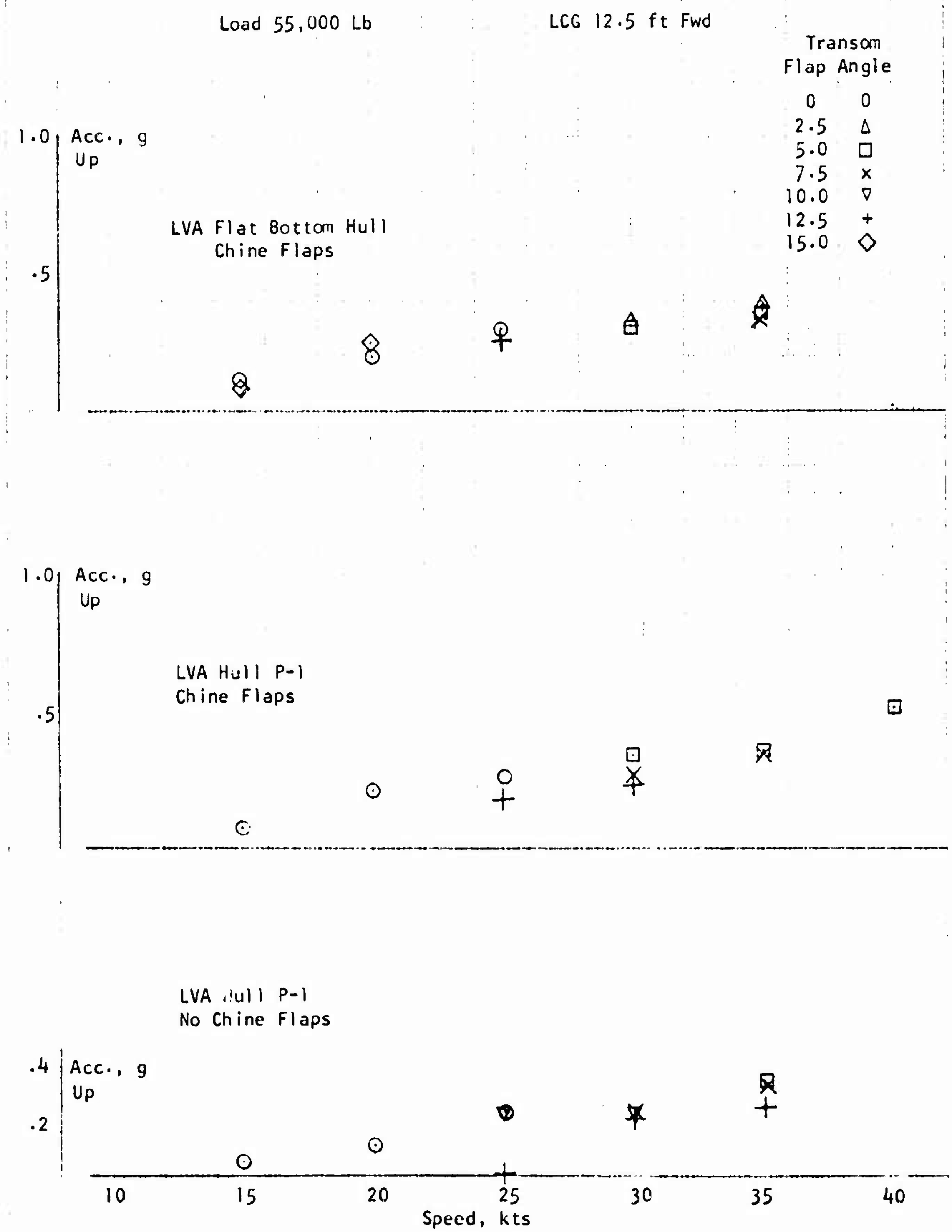


FIGURE 17
MEAN EFFECTIVE HORSEPOWER
SEA STATE 2

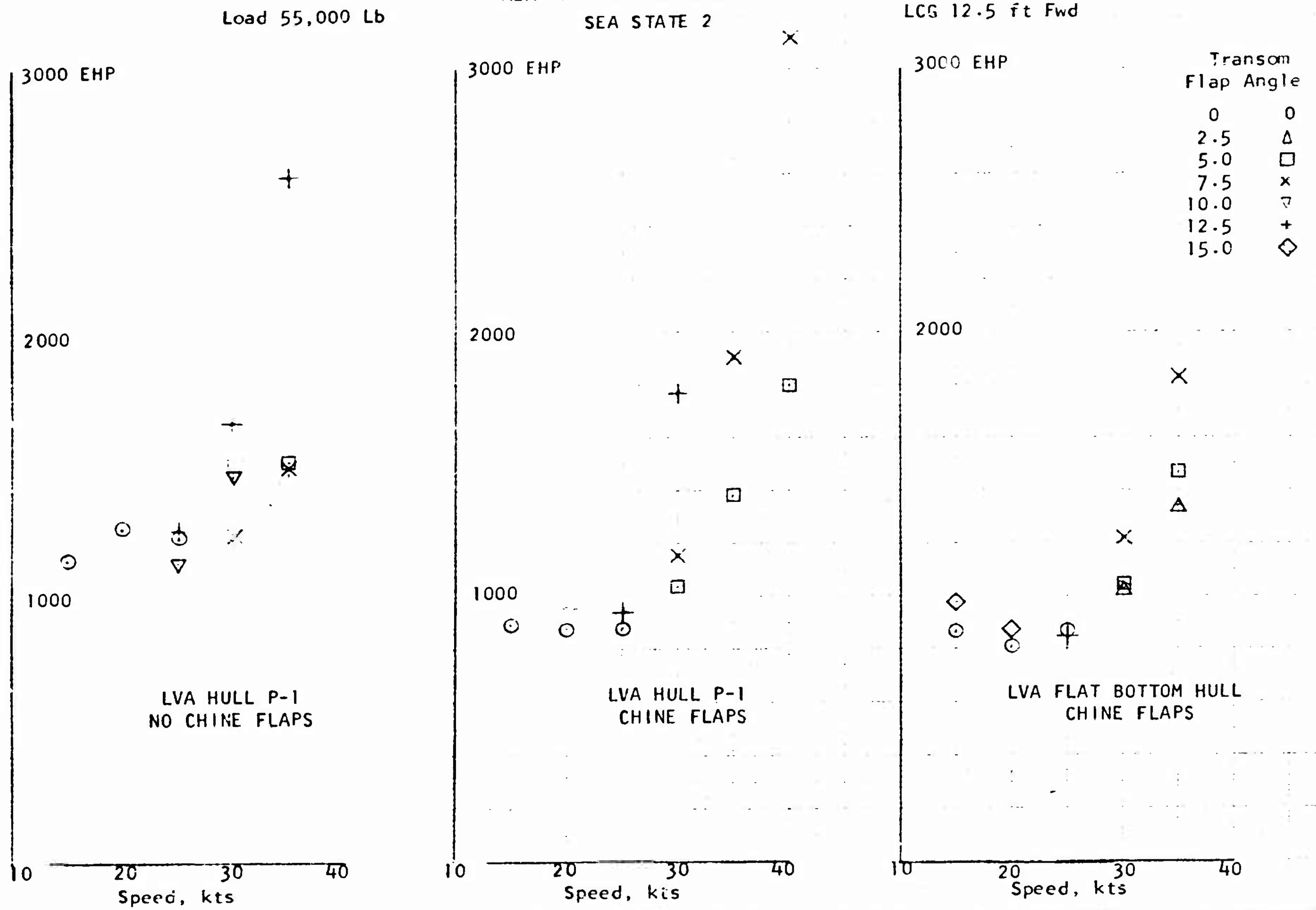


FIGURE 18

MEAN EFFECTIVE HORSEPOWER

HEAD SEA STATE 2

Δ = 55,000 LBS.   LCG = 12.5 FT. F'W'D TRANSOM

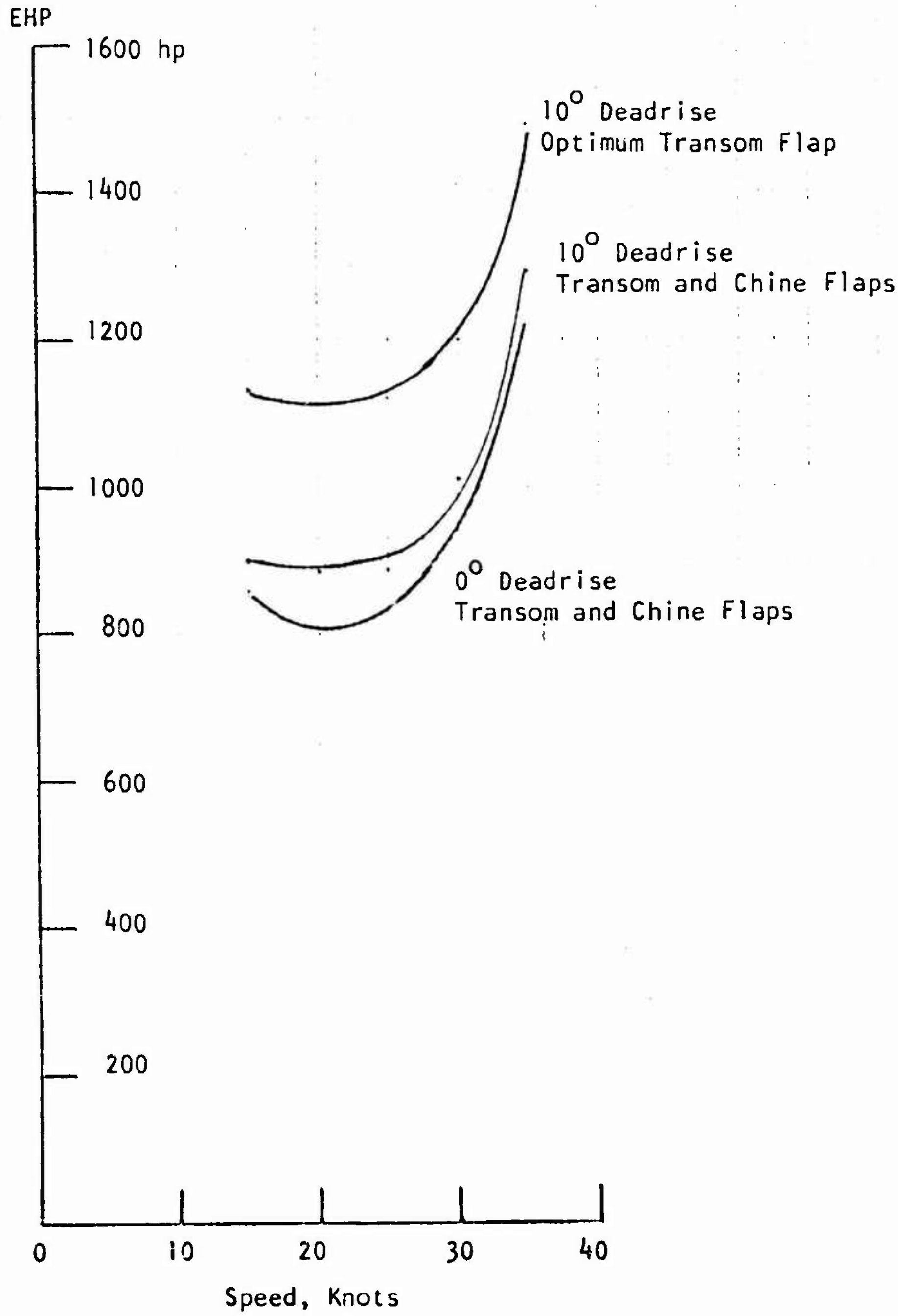


FIGURE 19

WAVE SPECTRA
Significant Height 2.2 Ft
Sea State 2

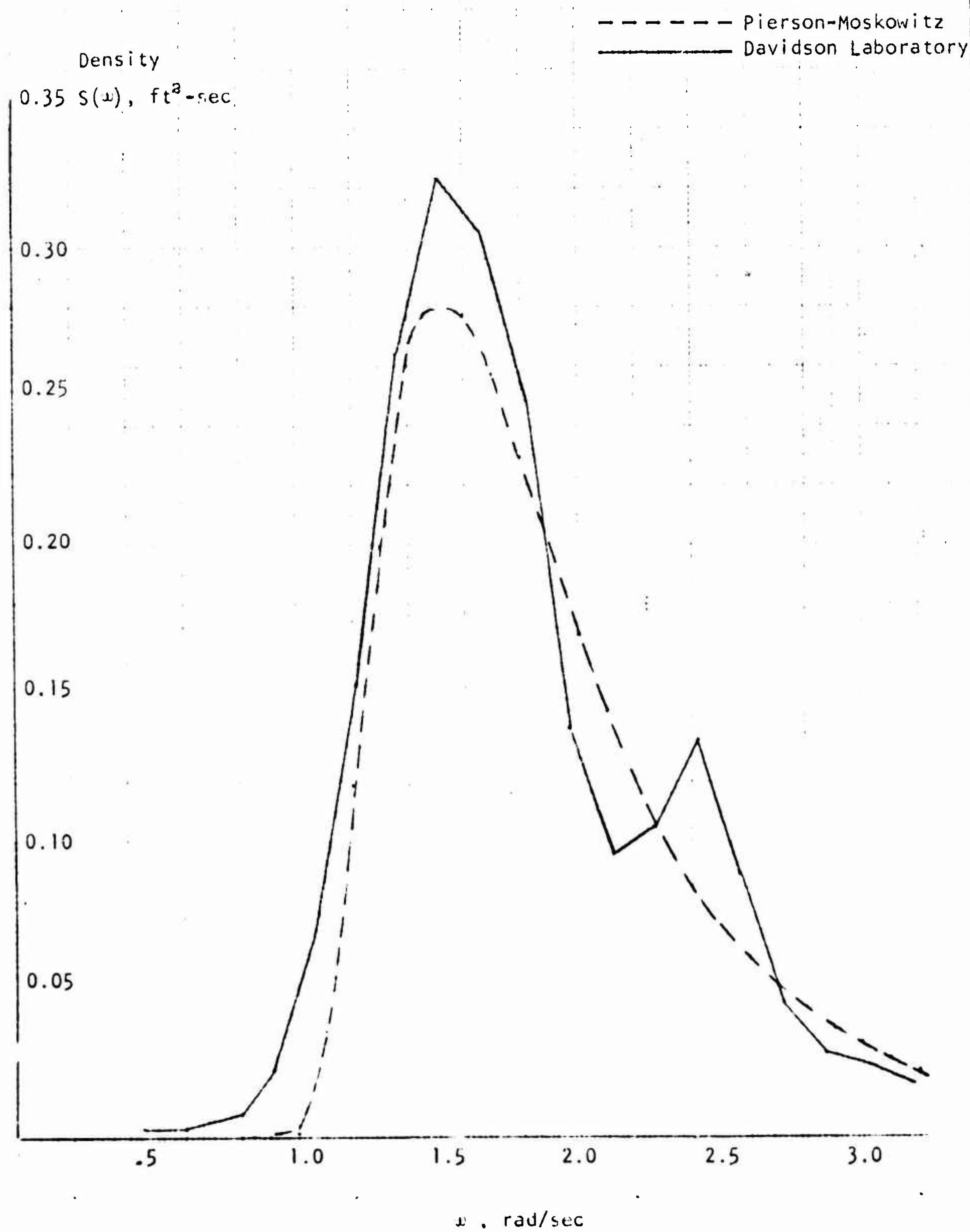


FIGURE 20

COMPARISON OF SIGNIFICANT ACCELERATIONS AT CG
FOR LVA AND CRAFT OF VARIOUS LENGTHS

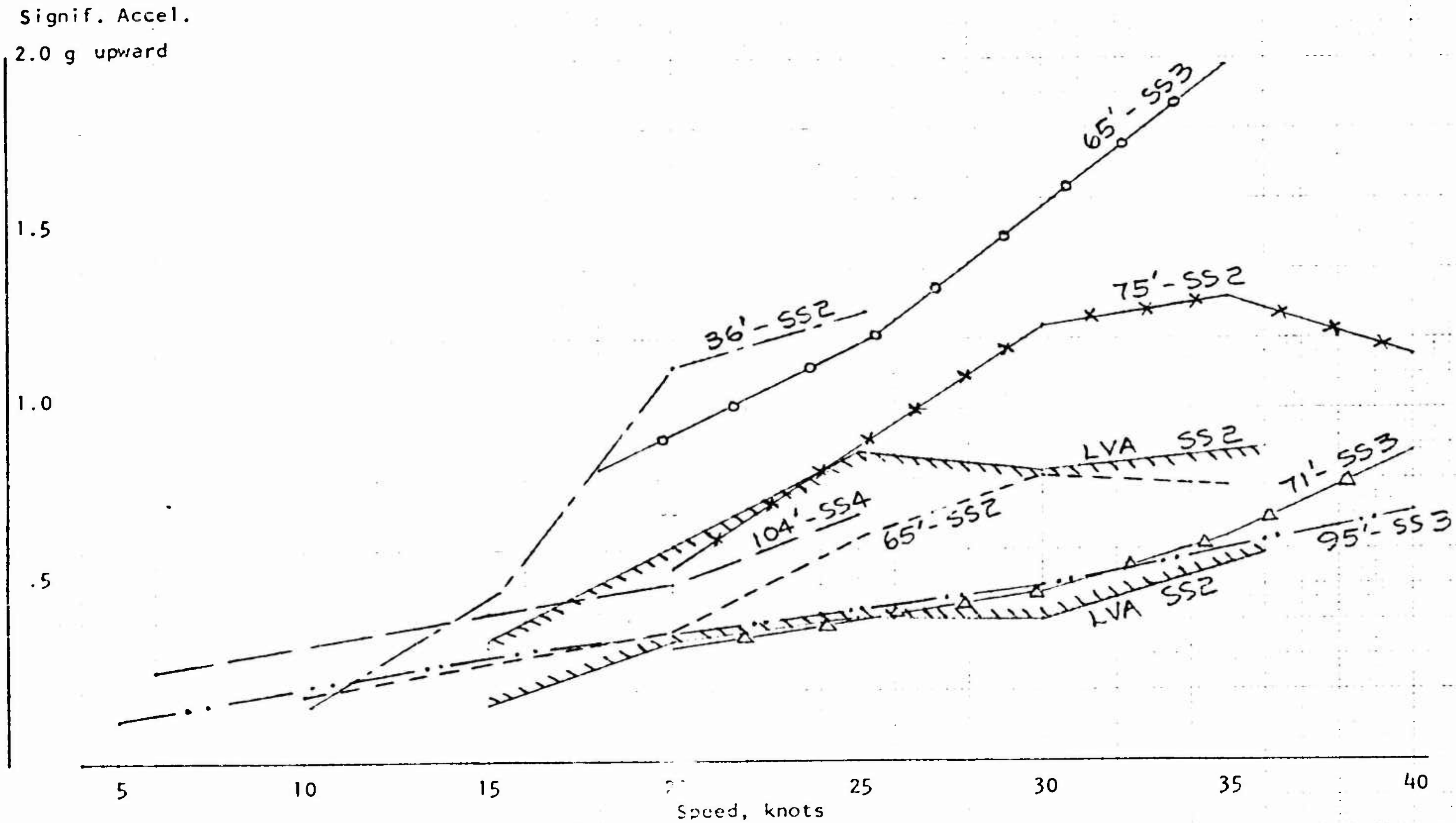


FIGURE 21

C.G. ACCELERATIONS VS. AVERAGE ENCOUNTER FREQUENCY

(Based on Davidson Laboratory Model Tests)

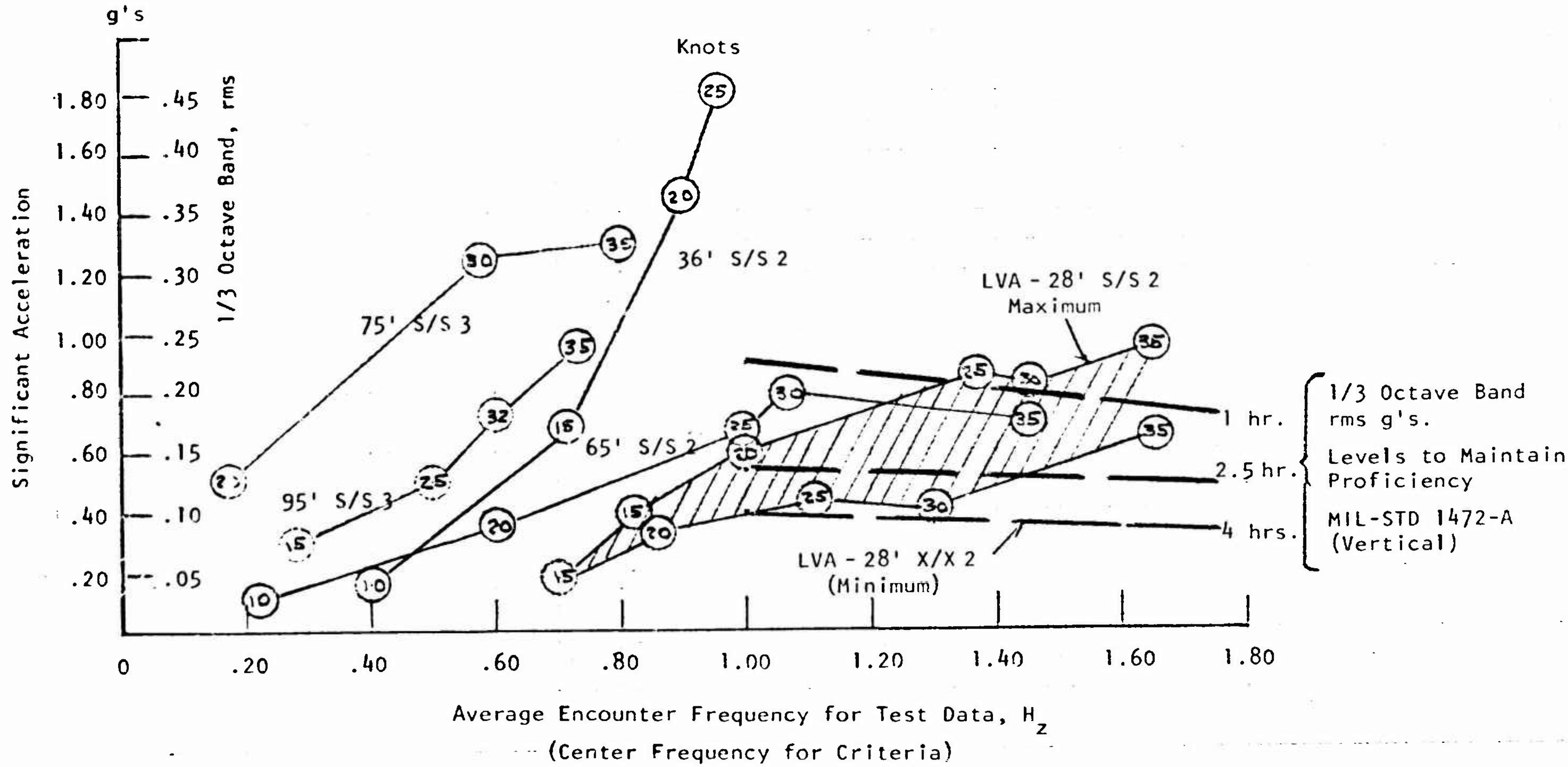
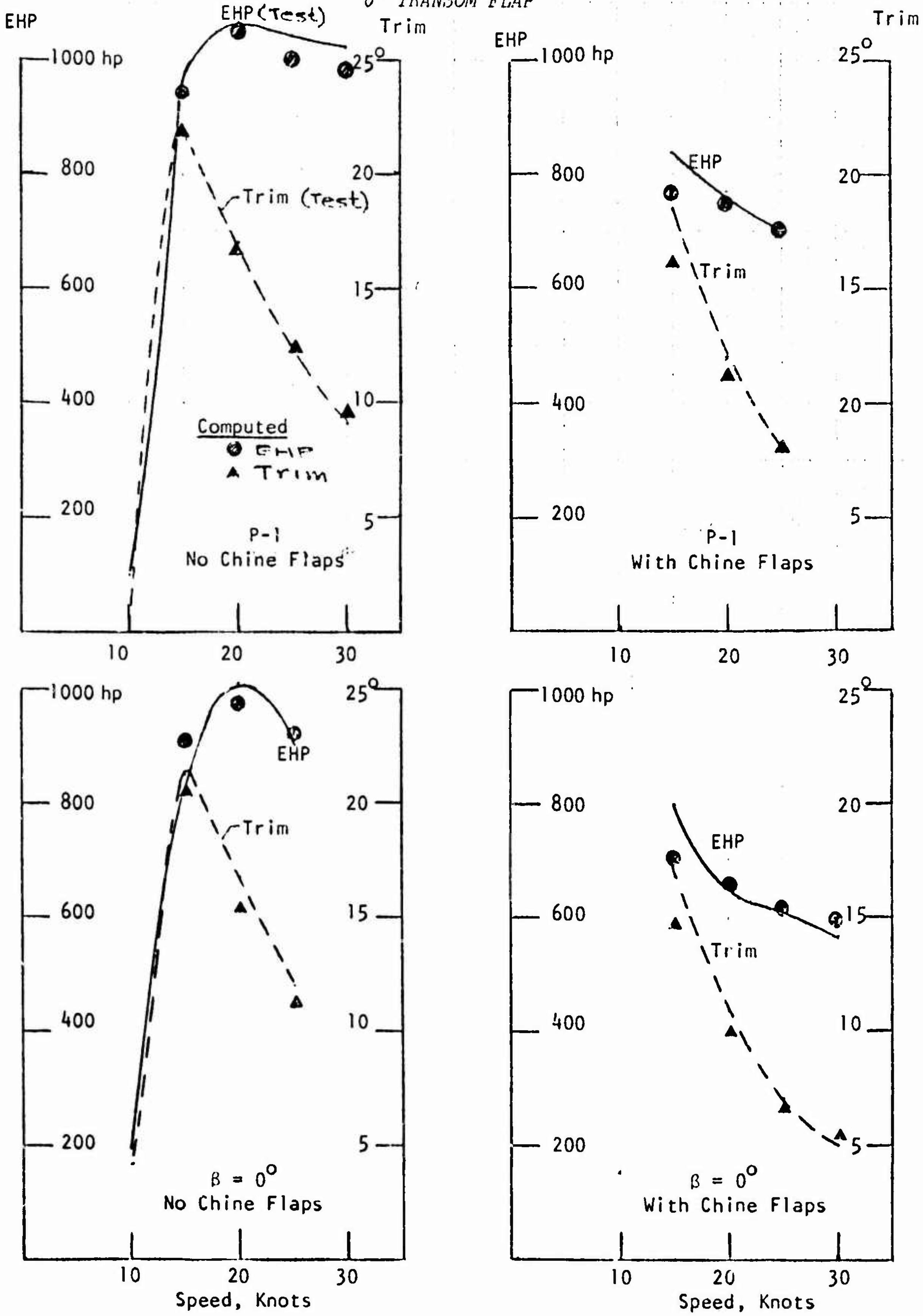


FIGURE 22

COMPARISON OF COMPUTED AND MEASURED RESULTS

0° TRANSOM FLAP



APPENDIX A

Movie Sequence

Reel 1

LVA P-1 Hull — No Chine Flaps

Speed kts	Transom Flap Angle deg	Sea State
15	15	0
15	15	2
20	15	2
25	12.5	0
25	12.5	2
30	7.5	0
30	7.5	2
35	7.5	0
35	7.5	2

Reel 2

LVA P-1 Hull — With Chine Flaps

15	15	0
20	15	0
25	12.5	0
25	12.5	2
30	7.5	0
30	7.5	2
35	5.0	0
35	5.0	2

APPENDIX A
(cont'd)

Reel 3

LVA Flat Bottom Hull With Chine Flaps

Speed kts	Transom Flap Angle deg	Sea State
15	15	0
15	15	2
20	15	0
20	15	2
25	12.5	0
25	12.5	2
30	5.0	0
30	5.0	2
35	5.0	0
35	5.0	2
Large Transom Flap		
15	2.5	0

APPENDIX B

LVA HULL P-1
SMOOTH WATER TEST MATRIX

P indicates porpoising

Load lb	LCG ft	Speed knots	WITHOUT CHINE FLAPS Transom Flap Angle, deg							WITH CHINE FLAPS Transom Flap Angle, deg							Speed knots
			0	2.5	5.0	7.5	10.0	12.5	15.0	0	2.5	5.0	7.5	10.0	12.5	15.0	
50,000	12.5	10	x														10
		15	x														15
		20	x														20
		25	x														25
		30	P														30
		35															35
		40															40
55,000	12.5	10	x														10
		15	x						x	x						x	15
		20	x						x	x						x	20
		25	x					x		x					x		25
		30	P			x				P	x	x	x		x		30
		35			x	x	x	x				x	x				35
		40			x	x						x	x				40
60,000	12.5	10	x														10
		15	x						x								15
		20	x					x	x								20
		25	x		x		x	x									25
		30	P	x	x	x	x	x									30
		35			x		x	x									35
		40			x	x											40
55,000	13.5	10															10
		15	x						x								15
		20	x						x								20
		25	x														25
		30	x			x											30
		35	P		x	x	x										35
		40			x	x											40

APPENDIX C

LVA FLAT BOTTOM HULL
SMOOTH WATER TEST MATRIX

Legend:
P porpoising
LT large transom flap

			WITHOUT CHINE FLAPS Transom Flap Angle, deg							WITH CHINE FLAPS Transom Flap Angle, deg							
Load lb	LCG ft	Speed knots	0	2.5	5.0	7.5	10.0	12.5	15.0	0	2.5	5.0	7.5	10.0	12.5	15.0	Speed knots
55,000	12.5	10	x														10
		15	x						x	x	LT	LT				x	15
		20	x					x	x	x	LT					x	20
		25	x				x	x		x					x		25
		30	P			x	x			x	x	x	x				30
		35		x	x	x				P	x	x	x				35
		40		x	x						x	x					40

APPENDIX D

LVA HULL

Irregular Seas Test Matrix

Load: 55,000 lbs
LCG: 12.5 ft

	Transom Flap Angle, Deg.						
Speed	0	2.5	5.0	7.5	10	12.5	15
LVA P-1 Without Chine Flaps							
15	x						x
20	x						x
25	x				x	x	
30				x	x	x	
35			x	x		x	
40							
LVA P-1 With Chine Flaps							
15	x						
20	x						
25	x					x	
30			x	x		x	
35			x	x			
40			x	x			
LVA FLAT BOTTOM HULL WITH CHINE FLAPS							
15	x						x
20	x						x
25	x						
30		x	x	x			
35		x	x	x			
40							

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